TABLE 2.—*Money loss by floods of January, 1914.*

District.	Tangible property loss, buildings, highways, etc.	Farms and farm property, including prospective crops.	Stock and movable property.	Total.
South Carolina			$400	$400
California:				
Sacramento	$370,000	$200,000	1,000	571,600
San Joaquin	80,000	5,500	600	91,000

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

FRESHETS IN THE SAVANNAH RIVER

AND THE FORECASTING OF HIGH WATER AT AUGUSTA, GA.

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[Dated May 16, 1913; revised December, 1914.]

PREFACE.

This paper is chiefly an explanation and discussion of the river forecast scheme that is used successfully by the writer in predicting high river stages for the benefit of the business and residential interests of Augusta, Ga., and the river farmers, lumbermen, and navigators below Augusta. It is hoped it may prove helpful to river forecasters elsewhere, and interesting to students of river flow.

Acknowledgements are due and are gratefully extended to Profs. H. C. Frankenfield and A. J. Henry, and Mr. H. W. Smith, of the Central Office of the Weather Bureau, Messrs. M. R. Hall and W. E. Hall of the United States Geological Survey, Judge Henry C. Hammond, of Augusta, Hon. Nisbet Wingfield, chief engineer of the river and canal commission of Augusta, and others who have furnished valuable historical and scientific facts and publications, as well as to the office force of the Augusta office of the United States Weather Bureau for assistance on tabular matter and diagrams.

THE SAVANNAH RIVER.

The Savannah River is a stream bold in all of its features. It is formed by the junction of the Seneca and Tugaloo Rivers about 100 miles above Augusta, Ga. The headwaters of the Seneca River are small streams having their origin chiefly in the mountains of South Carolina. The Tugaloo River results from small streams that rise for the most part in the mountains of north Georgia. Numerous creeks and small rivers enter these tributaries and the other tributaries of the Savannah River as well as the main stream. On the South Carolina side, Rocky River, Little River, and Stevens Creek are the most important streams, while on the Georgia side are found the Broad River, which is the largest of the tributaries, and the Little River, another important stream.

Por its size the Savannah River is an unusually restless stream, sensitive to even small amount of rainfall and subject to frequent rises. Here rushing in cascades over the granite bed, there resting in placid shoals, the the water makes on the whole rapid progres; the total fall in 64 miles immediately above Augusta is 257 feet The course is somewhat irregular and islands are quite numerous in the channel. The last of the cascades begins about 6 miles above Augusta and ends at Augusta, below which point navigable waters move leisurely along a winding course through the low swamps of the Coastal Plain to the Atlantic Ocean. It has been estimated that the Savannah River and the streams tributary to it are capable of generating a minimum of 200,000 horsepower, of which but a small amount is developed.

Topography and Geology.

Practically all of the catchment basin of the Savannah River above Augusta occupies the Piedmont Plateau. It is characterized by a truly rugged topography of clay hills overlying geologic formations of granite and gneiss. Elevations range from about 200 feet above sea level at the eastern edge of the plateau to 1,000 feet on its western edge. In remote mountain districts the general altitude is about 2,000 feet, with prominences considerably higher. The area of the watershed is 7,294 square miles.

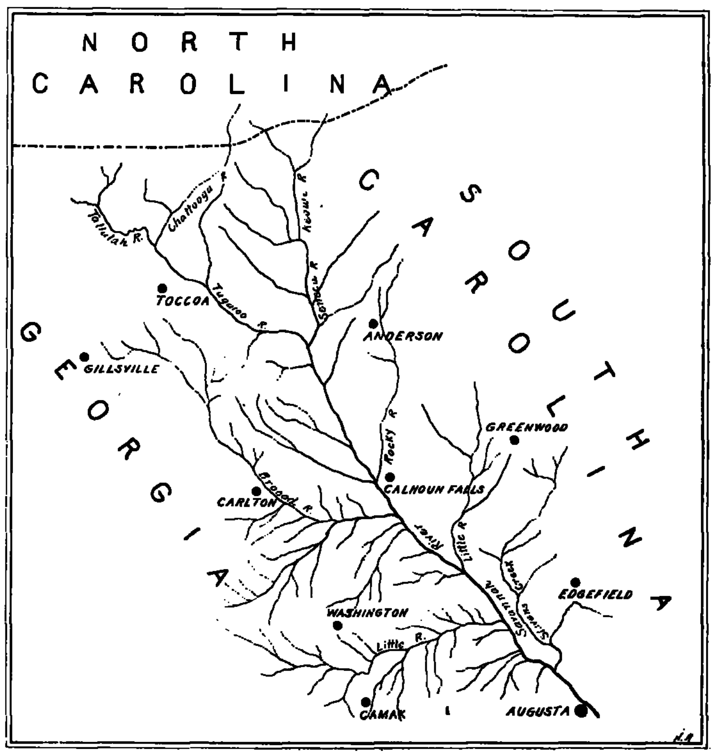

FIG. 1.—The Savannah River watershed above Augusta, Ga. Area 7,294 square miles.

Forestry conditions.

The South Carolina State Department of Agriculture, Commerce and Industries has published "Bulletin 1, January, 1910. Forest conditions in South Carolina. Report of Preliminary Examination and Survey. By W. M. Moore, forest assistant, United States Bureau of Forestry, Columbia, S. C., 1910." This report gives a description of past and present forest conditions that applies to the Savannah River watershed. The following is copied from his report:

Alpine region—Only about 25 per cent of this region has been cleared of forest, and many fields that have been cleared have after wards been abandoned. Red oak, blackjack oak, black oak, chestnut, black locust, scrub pine, and shortleaf pine are the principal trees of the higher altitudes. At the highest elevations white pine, hemlock, and fir are sometimes found, this being practically the southern limit of their range. On the lower slopes are found white, post, blackjack, swamp white, and red oaks, red and mountain maples, hickories, chestnut, black walnut, butternut, black locust, sweet gum, black gum, tulip poplar, basswood, white ash, red cedar, and shortleaf, scrub, and pitch pines. The oaks form a large part of the stand. The undergrowth consists largely of small seedlings and sprouts of the species mentioned, together with mountain laurel, rhododendron, huckleberries, blackberries, and asters and other herbaceous plants. There is not much grass, but ferns, mosses, and liverworts abound.

Piedmont region.—The entire Piedmont region was once well forested, though only about 25 per cent is in forests now. This is natural, since the region is distinctly agricultural, and the climate is healthful and invigorating throughout the year. The forest which remains is largely on rough land, along river courses, and in farm wood lots. The prevailing forest consists principally of short-leaf pine. Mixed with the pine in varying proportions and in various localities were oaks, such as white, post, overcup, chestnut, scarlet, black, shingle, and blackjack, chestnut, black walnut, black locust, sweet gum, black gum, ash, basswood, and tulip poplar. The most common trees along the river courses are sweet gum, sycamore, tulip poplar, black willow, white oak, post oak, and shortleaf pine. Gum, sycamore, and tulip poplar reach large size.

Wood lots of various sizes are well distributed throughout the Piedmont region, since a portion of nearly every farm has been kept in timber. The most abundant tree in these wood lots is shortleaf pine, known also as "woods pine" and "heart pine." It sometimes grows in pure stands, but it is generally mixed with oaks, hickories, and other hardwoods. Shortleaf pine is a prolific cone bearer and a quick seeder. Wherever fires are kept out its reproduction is excellent, and young seedlings are found in nearly every wood lot, though they do not thrive in deep shade. Many fields which were abandoned 40 or 50 years ago have grown to dense stands of this pine, which is now of merchantable size. Fields that are occasionally abandoned now because the topsoil is washed away are soon covered with thickets of short-leaf pine.

Since the roots form a network which holds the soil in place the tree is of great value on eroding hillsides. A good illustration is furnished by a field in Greenville County, S. C., which had been cultivated up to 20 years ago. The present owners kept out fires and piled brush in the gullies which were forming. The hillside field is now thickly covered with pines about 20 feet high, the largest of them being 7 inches in diameter. The crown cover is practically continuous and a dense mat of needles on the ground makes forest conditions complete. Tulip poplars are now beginning to come on.

RELATION OF FORESTS TO STORAGE AND CONSERVATION OF WATER.

A dense cover of forest, principally of pine, has been described as having blanketed the Savannah River watershed. The effect of such a forest upon the storage and retention of water for the future use of streams may be summarized as follows:

1. Considerable quantities of water caught and held in suspension by the trees and undergrowth are returned directly into the air by evaporation. The total loss on this account in the course of a year is fully worthy of mention.

2. Much of the water which penetrates through the trees runs off on the steep slopes that characterize the region.

3. A portion of the rain water passes through the needle mulch and forest humus and augments the ground-water supply.

4. The greatest and most far-reaching loss of soil water so far as the maintenance of stream flow is concerned is due to transpiration by the trees and plants of the forest. Penetrating in all directions and reaching deep into the ground, the roots take up vast quantities of water, which pass through the trunks, branches, and foliage to sustain plant life and promote growth and is evaporated.

5. Considerable loss of moisture occurs through evaporation from the forest floor.

Compared with the great losses occasioned by transpiration, the depletion of soil moisture by evaporation from the surface of the forest soil is, of course, of minor importance. It is, however, very persistent in this southern climate, and its volume depends upon this fact rather than upon great intensity. Undoubtedly the total evaporation from bare uncultivated land in the open in hot weather is as great or greater than from the forest humus, and in cool weather decidedly greater.

In recent years valuable investigations and experiments have been carried on by the United States Department of Agriculture, which are of interest in the consideration of any subject bearing upon the storage and conservation of moisture by the soil. It is interesting to note what these investigators have learned regarding the evaporation of moisture from the soil under different conditions.

The following is quoted from Dry Farming, by J. A. Widtsoe:

> It is an important fact that very dry soil furnishes a very effective protection against the capillary movement of water. In localities where the relative humidity is low, the temperature is high, and the sunshine abundant, evaporation may go on so rapidly that the lower layers can not supply the demand made upon it and the top soil then dries out so completely as to form a protecting covering against further evaporation.
>
> Direct sunshine is, next to temperature, the most active cause of rapid evaporation from moist soil surfaces. Whenever, therefore, evaporation is too slow to form a dry protecting layer of top soil, shading helps materially in reducing surface losses of soil water. Under very arid conditions, however, it is questionable whether in all cases shading has a really beneficial effect, though under semiarid and subhumid conditions the benefits derived from shading are increased largely.
>
> A special case of shading is the mulching of land with straw or other barnyard litter, or with leaves, as in the forest. Such mulching reduces evaporation, but only in part because of its shading action, since it acts also as a loose top layer of soil matter, breaking communication with the lower soil layers.
>
> Whenever the soil is carefully stirred, as will be described, the action of shading as a means of checking evaporation disappears almost entirely. It is only with soils that are tolerably moist at the surface that shading acts beneficially.

To avoid possible misinterpretation of the pages to follow, it will be well to lay stress upon the fact that there is a great difference between mere deforestation and deforestation attended by agricultural development. The former leaves the ground hard and bare and in a condition opposed to the absorption and conservation of moisture; the latter, especially under climatic conditions conducive to perennial cultivation, improves the ground water flow. In a hilly country, such as characterizes the Piedmont section of the Savannah Valley, terracing and advanced methods of cultivation have failed to overcome the tendency for freshets to increase with deforestation, while very active surface run-off results when the fields are uncultivated. In a denuded mountain region, with precipitous slopes, the run-off is extremely flashy, the freshets being torrential and the normal flow deficient. Nothing in this article should, therefore, be construed as an argument against the protection of forests in mountainous sections.

Forester W. M. Moore, in his report on South Carolina above quoted, says:

> The forests of the Alpine region are really protection forests and should be retained as such. The only way to protect the headwaters of the rivers and to prevent further damage to bottom lands, highways, bridges, and mills is for the Federal or State Government to purchase and manage the mountain forests.

In this view the writer entirely concurs.

CULTIVATION.

In the early days deep plowing was unknown in this section. Since then not only has there been an almost continuous increase in the area of agricultural lands, but farming methods have greatly improved. Practically all of the hillsides have been terraced and deep plowing is now a common practice, while about half of the cultivated area has been subjected to other modern methods. Hundreds of acres once hard and bare in the winter months are now verdant with oats, clover, and other winter cover crops. The dust mulch is much more commonly and more scientifically used than formerly, though it has always been necessary to cultivate corn and cotton quite vigorously until near the middle of July for the double purpose of keeping down the grass and conserving moisture in the soil for the later use of crops.

About October 1 plowing is commenced. Those who wish to put in winter cover crops push the work rapidly. Others plow intermittently all fall and winter. As a result, a large percentage of the land of the Savannah River watershed is in ideal condition to receive the rainfall of the storage period, which embraces the months of January, February, March, and April.

During March and early in April the clods not previously harrowed for winter crops are broken up and the planting of cotton and corn progresses. For about three months, usually from the middle of April to the middle of July, the ground is thoroughly hoed or cultivated after every rain, unless the precipitation is so heavy and frequent as to prevent the fields being entered. This is a most important period in its bearing upon the conservation of moisture, for when the rainfall is not so heavy as to either maintain or augment the ground-water supply in spite of evaporation the widespread dust mulch prevents evaporation and saves the moisture in the soil.

In "Dry Farming" Widtsoe quotes a number of reports of experiments which show that on the average the evaporation from soil on which there is a well-prepared dust mulch is about 60 per cent less than from compact bare soil.

To show the difference between evaporation on cultivated and noncultivated land on which crops are growing, the following table is copied from Utah Agricultural College Bulletin No. 115, "The Movement of Water in Irrigated Soils," by W. W. McLaughlin and J. A. Widtsoe.

TABLE I.—*Effect of cultivation on the rate of loss of soil moisture.*

[Year 1902. To a depth of 8 feet. Crops growing vigorously.]

Length of period (days after irrigation).	Average per cent of water at beginning.	Pounds of water lost per square foot.	Soil treatment.
Days.	*Per cent.*	*Lbs.*	
31	17.19	36.28	No cultivation.
31	17.48	30.99	Cultivated weekly.
		5.29	
20	16.67	22.37	No cultivation.
20	14.78	16.84	Cultivated weekly.
		5.53	
20	16.95	15.87	No cultivation.
20	17.59	12.38	Cultivated weekly.
		3.49	

From these figures the difference in the amount of water evaporated from thoroughly cultivated land and from ordinary agricultural land, with crops growing on both, may readily amount to 1 inch in a month. If it be assumed that one-half of the Savannah watershed is thoroughly tilled from the middle of April to the middle of July and the other half in an ordinary state of cultivation, with crops growing (though only about 20 per cent is actually in such condition and the remaining 30 per cent is largely woodland), the saving in three months for the entire shed would be 1½ inches. This, if devoted in its entirety to river flow, would maintain a stage of over 5 feet at Augusta for three months, or it would represent the difference between a 5.5-foot stage and an 8-foot stage for three months though, of course, not nearly all the water saved reaches the streams. This is merely by way of illustration, some knowledge of the factors affecting the soil's content of moisture being helpful to the river forecaster.

Agricultural development in the Savannah Valley may be safely presumed to have closely accorded with that of other portions of the Piedmont region. It will be assumed therefore, that 25 per cent of the catchment area remained covered with trees in 1909, as indicated by Mr. W. M. Moore in his report on forestry in the Piedmont section of South Carolina. Allowing 10 per cent of the area for roads and other bare ground, the remaining 65 per cent will be considered as agricultural land, cultivated for the most part though partly in pasture.

The decrease in forested area may for all practical purposes be assumed to have been proportional to the increase in agricultural lands. It being a known fact that acreage in cotton is an accurate index to agricultural activity in this section and the statistics for this crop being the only figures available for a long period of years, computations of areas have been based thereon. The following Table II is the result.

TABLE II.—*Percentage of woodland, agricultural land, and bare land in the Savannah River watershed above Augusta.*

Year.	Wood-land.	Agricultural land.	Bare land.	Cotton, Georgia and South Carolina.
	Per cent.	*Per cent.*	*Per cent.*	*Acres.*
1859	70	20	10	[1] 2,532,600
1869	74	16	10	[2] 1,703,400
1870	72	18	10	....
1871	70	20	10	....
1872	68	22	10	....
1873	66	24	10	....
1874	64	26	10	[3] 2,850,000
1875	62	28	10	....
1876	60	30	10	....
1877	58	32	10	....
1878	56	34	10	....
1879	54	36	10	3,981,400
1880	53	37	10	....
1881	52	38	10	....
1882	51	39	10	....
1883	50	40	10	....
1884	48	42	10	4,675,000
1885	47	43	10	....
1886	46	44	10	....
1887	44	46	10	....
1888	43	47	10	....
1889	41	49	10	5,332,500
1890	41	49	10	....
1891	40	50	10	....
1892	39	51	10	....
1893	39	51	10	4,905,000
1894	38	52	10	5,771,400
1895	38	52	10	4,884,000
1896	38	52	10	5,482,000
1897	38	52	10	5,613,000
1898	37	53	10	5,888,000
1899	37	53	10	5,588,000
1900	36	54	10	5,978,000
1901	33	57	10	6,255,000
1902	33	57	10	6,069,000
1903	32	58	10	6,367,000
1904	29	61	10	6,759,000
1905	29	61	10	5,901,000
1906	27	63	10	6,989,000
1907	25	65	10	7,200,000
1908	23	67	10	7,393,000
1909	23	67	10	7,166,000
1910	21	69	10	7,596,000
1911	19	71	10	7,824,000
1912	19	71	10	7,625,000

[1] Estimated from production, allowing 3 acres for each bale of 500 pounds.
[2] Estimated from production, allowing yield per acre that obtained in 1879.
[3] Interpolated.

During the Civil War much land previously cultivated was abandoned. Complete recovery and return to the acreage of 1859 did not occur until 1870 or a little later, so that the prolific, quick-growing shortleaf pine had had ample time to restore the abandoned land to forest conditions, the pine thickets being equivalent to primal conditions in their effect upon run-off. The percentages given in the above table may, therefore, be accepted as accurate within a narrow margin of error.

Since 1870 the ratio between woodland and agricultural land has reversed. In 1870 forests covered approximately 70 per cent of the area of the Piedmont section of the watershed and agricultural land about 20 per cent. The alpine section is unnecessary to consider. At the present time woodland occupies only 20 per cent of its area, mostly in farm woodlots, while agricultural land occupies about 70 per cent.

SURFACE RUN-OFF—HIGH WATER STAGES.

Importance attaches to the 20-foot stage of the Savannah River at Augusta by reason of the fact that when it is reached some of the river farms below Augusta are inundated. It is also of interest to lumbermen, since it enables them to float logs out of the swamps, and to contractors working on Government and municipal developments along the river front and below the city, as well as to river transportation companies. Stages above 20 feet are of increasing importance as the depth increases, though water does not enter Augusta until the 32-foot stage is reached, and does not cause general concern until the 34-foot stage is attained, when a considerable area in the business section is affected. At 36 feet a wide area of the business and residence sections is covered to depths of from 1 to 3 feet.

RELATION OF SURFACE RUN-OF TO HIGH WATER.

Primary surface run-off is that which occurs practically simultaneously with the falling of the rain by which it is caused.

Secondary surface run-off may be defined as the more gradual discharge of water from thoroughly saturated surface soil or forest mulch and humus. It is quite pronounced under forest conditions, and is common from cultivated areas after slow, steady rainfall.

Chittenden and other writers have pointed out that delayed run-off from forests may considerably augment the volume of a freshet or flood in such a way as to counterbalance any tendency deforestation might have to occasion increases of high water in volume or frequency, the delayed flow lower down combining with the primary run-off from above. However that may be for longer rivers, in a short stream like the upper Savannah River freshets can be affected only when the delayed run-off from one rain that has supersaturated the surface soil combines with the primary run-off from another rain falling not more than two or three days later. Sequence of precipitation calculated to produce such an effect is found by detailed study of the daily values for the upper Savannah River for 20 years, to be unusual. It follows that for purposes of general discussion of the frequency and volume of high water at Augusta delayed run-off may be ignored, its only office being to maintain a somewhat more active flow after some freshets than would otherwise exist.

The number of days with the Savannah River at or above the 20-foot stage at Augusta has increased with the

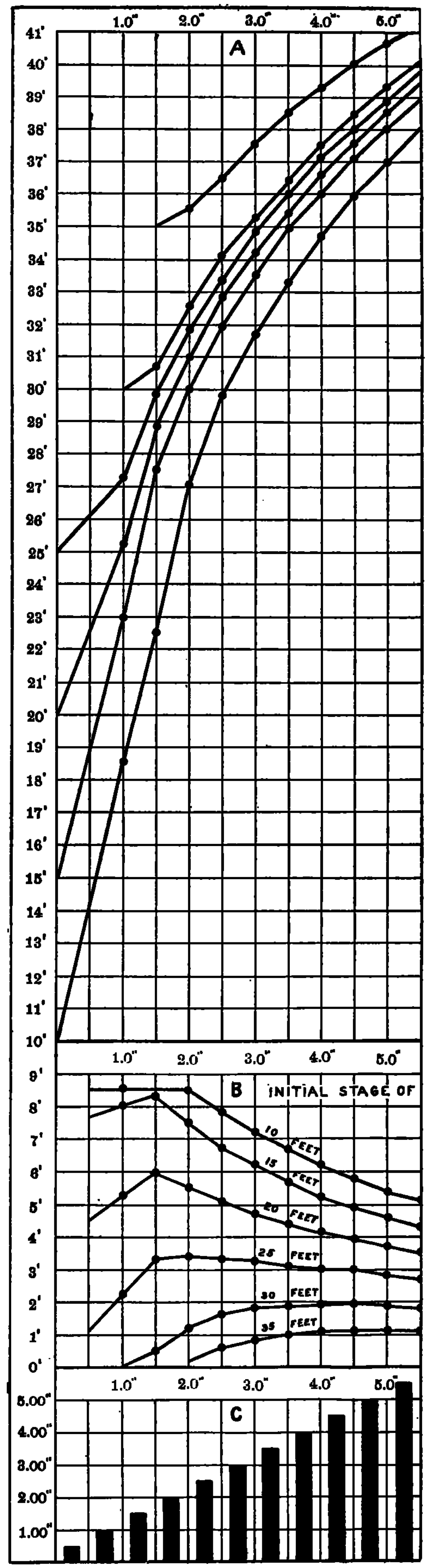

FIG. 2.—River forecast scheme. Diagram No. 1. Relation of 24-hour rainfall over the Savannah River watershed to river stages at Augusta, Ga. A. Initial and resulting stages. B. Rise per inch of rain. C. Rainfall in inches.

expansion of agricultural and contraction of forest area. It may be well to now attempt to fix the extent of this increase and ascertain its cause. This can be done with sufficient accuracy by the use of simple ratios.

During the 10 years 1877 to 1887 (1878 being omitted) the average rainfall for the storage period (January, February, March, and April) was 20.9 inches, and the average number of days with the river stage at Augusta at or above 20 feet was 8.4. During the 10 years 1902–1911 the average rainfall for the same months was 16.1 inches, and the average number of days of 20 feet or over, was 10. Although the rainfall in the first 10 years was 30 per cent more than in the last 10 years, the number of days in the first group of years with the river depth at Augusta 20 feet or over, was 20 per cent less than in the last.

In studying the above ratios it is important to remember that—

1. The amount of rise to reach 20 feet is not considered.
2. They figure from zero as the basis of computation of rainfall percentage, whereas only the amount of rain exceeding that below which the 20-foot stage is impossible should be considered.

The question may properly be asked whether the demonstrated greater frequency of river depths of 20 feet and over necessarily indicates a more active surface run-off. Since the average river stage has increased in depth approximately 3 feet, less rainfall is now required than formerly to occasion a rise to any high-water stage on the Augusta gage.

Starting from initial stages below 16 feet, the normal amount of rise in the Savannah River at Augusta for each inch of rain in 24 hours over the catchment area with the ground in moist condition is 8.5 feet. This remains true until rain has brought the river to its 29-foot stage. Any surplus of water above that necessary to cause a 29-foot stage has a value of about 3 feet for each inch of rain. The 3 feet difference in gage readings added to the initial stages of the 1877–1887 group of years increases by 3 feet the original gage readings up to the 26-foot stage; by more than 2 feet the 27-foot stage; by nearly 2 feet the 28-foot stage; and by about 1 foot all other gage readings up to about the 34-foot stage, where the effect becomes negligible. Nearly all rises now, and formerly a greater proportion of them, originated below the 16-foot stage. For the purpose in hand, the few rises starting from stages above 16 feet may be included without serious effect on the result.

If, instead of figuring from zero as the basis of computation of rainfall percentages, we take into account only rainfall above the amount below which the 20-foot stage is impossible, the following results are obtained:

At the present time about 12 inches of rain is required during the first four months of the year in order that the 20-foot stage may become possible. Snow seldom falls and never has any appreciable effect on the river's recorded stages, being followed by cold weather and slow melting.

During the 10 years 1877–1887 (1878 being omitted) there were 14.7 days, on the average, with river stages of 17 feet or over, during the first four months of the year; this would be equivalent to the number of days 20 feet or over had the initial stage been 3 feet higher, as in the 1902–1911 group of years. A comparison of these 14.7 days of 17 feet or over with the 10 days' average for stages of 20 feet or over in the 1902–1911 group of years, shows the former to have been 47 per cent greater.

Using the usual correlation formula, as used and explained by Prof. J. Warren Smith in his study of the Ohio River, it is found that there is a harmonious relation between the rainfall during January, February, March, and April and the number of days with the river above certain stages at Augusta, the probable error in each computation being negligible.

The following are the coefficients:

Comparing days 20 feet or above and rainfall: Coefficient for 1877–1887 = 0.85, with probable error ± 0.06.

Comparing days 17 feet or above and rainfall: Coefficient for 1877–1887 = 0.81, with probable error ± 0.08.

Comparing days 20 feet or above and rainfall: Coefficient for 1902–1911 = 0.96, with probable error ± 0.02.

In 1877–1887 the rainfall actively applied to producing days with stages of 17 feet or over was: $20.9 - 12.0 = 8.9$ inches.

In 1902–1911 the rainfall actively applied to producing days with stages of 20 feet or over was $16.1 - 12.0 = 4.1$ inches.

The amount of rainfall effective in producing comparable stages was, therefore, 117 per cent greater in 1877–1887 than in 1902–1911; the number of days with stages of 17 feet and over in the first group of years was only 47 per cent greater than the number of days with stages of 20 feet and over in the last group. This shows an increase in surface run-off to which it is desirable to assign an approximately definite value.

Since the mean of the correlation coefficients of the two 10-year groups is about 0.90, and the average number of days with 20 feet or over in the 1902–1911 group is 10, the number of days with stages of 20 feet or over to be expected from 8.9 inches of effective rainfall during the first four months of the year under present run-off conditions is: $0.90 \times 2.17 \times 10.0 = 19.5$ days.

This is equivalent to 19.5 days with stages of 17 feet and over under original ground-water conditions and new surface run-off conditions and the following computation is in order, 20.9 inches of rainfall being assumed:

Let

a = Original average stream flow, days of 17 feet or over.

b = New surface run-off, days of 17 feet or over.

c = Forest surface run-off, days of 17 feet or over.

Then $a + b = 19.5$ days.

$a + c = 14.7$ days.

and $b - c = 4.8$ days = difference in effect of old and new surface run-off.

This corresponds to 4.8 days of 20 feet or over now and since the average number of days of 20 feet or over in 1877–1887 was 8.4 and the same rainfall now should cause 19.5 days, the number of days increase due to increase in depth of average stream flow may be ascertained as follows:

$19.5 - 8.4 = 11.1$ days, increase for 20.9 inches of rain.

Of these 11.1 days, 4.8 are due to greater surface flow.

Therefore, $11.1 - 4.8 = 6.3$ days of the increase are due to an increase of 3 feet in depth of average stream flow.

The above discussion being somewhat empirical, it will be well to inspect the records to determine the accuracy of the conclusion that 21 inches of rain in the first four months of the year will ordinarily cause the river at Augusta to be 20 feet deep or more during 20 days of that time.

Year.	Rainfall, January-April.	Days of 20 feet or over.
1903	24.6	23
1906	17.8	14
1908	19.8	24
1909	18.2	12
1912	25.2	25
Means	21.1	20

The criticism may be raised that the argument presented deals indiscriminately with all stages above 20 feet without regard to the volume of the freshets. This, however, is only an apparent, not a real, objection. The number of days of 20 feet or over is dependent on the effective amount of rainfall. If the precipitation be of short duration but great intensity, it occasions a high stage that keeps the river above 20 feet for several days. If the rainfall be of the same amount but lower intensity, extending over two or three days instead of one, the result in terms of days 20 feet or over is practically the same, though the crest of the flood is somewhat lower. The formula used does include stages well above 20 feet and tends to indicate for them the same facts as are proven for the entire class of stages 20 feet or over.

The rise of March, 1912, which reached 36.8 feet on the gage, undoubtedly owed much of its extraordinary height to the absence of the forests. The ground was uncut by the plow and was thoroughly packed and saturated by the incessant abnormal rainfall of several months that had prevented field work of any kind. The hillsides, therefore, presented hard, smooth inclines, from which the flow was so rapid that the water piled up in the river and had no opportunity to level out before it reached Augusta. The obstructions presented by a forest or by cultivated fields would have given a much better regulated flow.

Aside from extremely rare occurrences such as that of 1912, however, the increase in surface run-off of the present time over that of earlier years is largely and probably entirely attributable to the fact that under forest conditions more rain was required to bring the surface run-off to its maximum volume, and not to greater activity of the run-off when once established. If, therefore, as is occasionally the case, at the beginning of a period of heavy rainfall a considerable quantity of water must be retained to wet the soil, then the ultimate river stages must necessarily be affected according to the amount of water thus withheld from the main streams. The greater surface run-off of the present day and the greater depth of normal flow combined, can readily be shown to have an important effect even on very high river stages when the capacity of the surface soil for moisture has not been previously satisfied and the rainfall producing the high stage is of only one or two days' duration.

The 24-hour rainfall equivalent of the 3-foot difference in normal stage is 0.35 inch.

The 3-foot difference in normal stage caused an increase in the number of days when the river at Augusta was 20 feet or over, of 6.3 days.

Increased surface run-off caused a difference in the number of days when the river was 20 feet or over at Augusta, of 4.8 days.

Now 6.3 : 4.8 :: 0.35 : 0.27; consequently 0.27 inch is the rainfall equivalent for increased surface run-off.

This makes the increased tendency for high stages, with the ground in ordinary condition, correspond to 0.62 inch of rain in 24 hours, and is capable of increasing stages as follows:

The 32-foot stage to 34 feet.
The 33-foot stage to 35 feet.
The 34-foot stage to 35.5 feet.
The 35-foot stage to 36.4 feet.
The 36-foot stage to 37.3 feet.
The 37-foot stage to 38.1 feet.

While it may be stated as a general proposition that the great freshets come only after the soil has been thoroughly saturated, and that the state of soil saturation is usually the result of previous rains, the importance of the class of exceptions above outlined should not be underestimated in considering a stream as flashy as is the Savannah River.

The greatest of all freshets, that of 1796, when, according to reliable estimates, the Savannah River at Augusta carried 40 feet of water, the Harrison freshet of 1840 and the rise of 1852, both of these being above 37 feet, occurred while the forests remained intact. On the other hand, eight of the twelve stages of 34 feet or over during the 73 years from May, 1840, to March, 1913, occurred in the last 26 years and included the great freshet of 1888, 38.7 feet, and that of 1908, 38.8 feet. Three of the twelve have been recorded in the past five years.

TABLE III.—*River stages of 34 feet and over in the Savannah River at Augusta, Ga.*

Year.	Stage.	Date.
	Feet.	
1796	[1] 40	February.
1840	37.8	May 28.
1852	37.4	Aug. 29.
1864	34.9	Jan. 1.
1865	36.9	Jan. 11.
1887	34.6	July 31.
1887	34.3	Aug. 10.
1888	38.7	Sept. 11.
1891	35.5	Mar. 9.
1902	34.6	Mar. 1.
1908	38.8	Aug. 27.
1912	36.8	Mar. 16.
1913	35.1	Mar. 16.

[1] Estimated.

TABLE IV.—*Savannah River stages of 25 feet and over at Augusta, Ga., September, 1875, to December, 1912.*

Year.	Jan.		Feb.		Mar.		Apr.		May.		June.		July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.	Stage	Date.
	Feet.		*Feet.*		*Feet.*		*Feet.*		*Feet.*		*Feet.*		*Feet.*		*Feet.*		*Feet.*		*Feet.*		*Feet.*		*Feet.*	
1875[1]																							27.4	30
1876							25.6	12																
1877							29.8	14																
1878																								
1879																							30.1	16
1880					28.4	17																		
1881	30.5	21	29.5 28.4	11 13	32.2 30.7	18 20																		
1882			26.8 27.0	5 10													29.4	12						
1883	30.8	22					27.5 25.5	11 24																
1884					26.2 26.3	14 21	28.0	16			25.8	26												
1885	27.6	26																						
1886	30.5	5					32.2	1	32.5	21			27.9	2										
1887													34.6	31	33.3 34.3	4 10								
1888	25.6	3	29.2	26	32.8	30											38.7	11			25.8	16		
1889	25.1	28	33.3	18																				
1890																			28.5 27.9	1 24				
1891			27.6	9	35.5 31.3 29.1	10 13 28									25.4	28								
1892	29.4 32.8	15 20	26.4	22	27.6	27	25.6	9																
1893			25.4	14																				
1894																			27.7	10			26.2	13
1895	30.5	11			28.5	16									30.5	23								
1896													30.5	9										
1897			27.5	7	25.6	15	29.3	6																
1898			25.0	17													28.5	2						
1899			31.0 30.2	8 28	28.8 25.5	1 17																		
1900			32.7	14			25.2 28.0	19 22			29.4	25												
1901			27.3	5	29.8	27	31.8	4	27.7	23	27.2	15			29.1	29	31.6	19					31.0	31
1902			32.6	3	34.6 28.5	1 17																		
1903			33.2 28.8 29.9	9 12 18	27.0 28.4 30.0 27.6	1 30 25 31					27.3	8												
1904															25.5	10								
1905			25.8	14																			28.3	22
1906	29.6 29.1	5 24			25.0 28.6	16 21																		
1907																							28.8 28.0	24 31
1908	27.4	13	27.6 25.8 26.0	2 12 17	29.8	25									38.8	27							26.5	23
1909			28.1 26.4	11 24	26.7 28.0	11 15			25.9	2	28.7	5												
1910					26.4	2																		
1911																							31.5	24
1912			29.9 24.9	16 27	25.8 36.8 25.8	7 16 30	26.5	23			25.3	16									27.4	7		

[1] No record until September, 1875.

TABLE V.—*Number of days the Savannah River was 20 feet or over at Augusta, Ga.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1875	...	...	...	...	...	...	...	...	0	0	0	2	...
1876	1	0	1	3	0	0	0	0	0	0	0	0	5
1877	0	1	1	3	0	0	0	0	0	0	2	0	7
1878	1	3	0	0	0	0	0	0	0	0	0	0	4
1879	0	0	0	0	0	0	0	1	0	2	0	3	6
1880	0	0	8	1	0	0	0	0	0	0	0	1	10
1881	4	5	5	0	0	0	0	0	0	0	0	3	17
1882	0	6	4	0	0	0	0	0	3	0	0	1	14
1883	9	0	0	3	0	0	0	0	0	0	0	0	12
1884	1	2	13	3	0	3	0	0	0	0	0	1	23
1885	5	2	0	0	0	0	0	0	1	0	0	0	8
1886	3	0	2	3	4	0	2	0	0	0	0	0	14
1887	0	0	0	0	0	0	2	10	0	0	0	0	12
1888	2	3	6	1	1	0	0	0	10	1	4	0	28
1889	5	8	1	0	0	0	1	0	0	0	0	0	15
1890	0	1	1	0	1	0	0	0	1	4	0	0	8
1891	2	10	10	3	0	0	0	3	0	0	0	0	28
1892	10	2	2	3	0	0	3	0	1	0	0	0	21
1893	0	5	1	0	0	0	0	3	0	0	0	0	9
1894	0	2	1	0	0	0	0	4	0	2	0	2	11
1895	5	0	5	1	0	0	0	2	0	0	0	0	13
1896	1	4	0	0	0	0	5	0	0	0	1	0	11
1897	1	6	4	2	0	0	0	0	0	0	0	0	13
1898	0	0	0	0	0	0	0	0	3	2	0	1	6
1899	1	8	7	0	0	0	0	0	0	0	0	0	16
1900	0	5	2	6	0	5	0	0	0	0	0	0	18
1901	2	3	3	5	3	3	0	8	5	0	0	3	33
1902	1	4	9	1	0	0	0	0	0	0	0	1	16
1903	0	11	9	3	0	2	0	0	0	0	0	0	25
1904	0	0	0	0	0	0	0	3	0	0	0	0	3
1905	0	5	0	0	0	0	3	0	0	0	0	3	11
1906	9	0	5	0	0	5	2	0	2	2	0	0	25
1907	1	1	0	0	0	0	0	0	0	0	3	6	11
1908	7	9	4	4	0	0	0	5	1	0	0	2	32
1909	1	5	6	0	3	3	1	1	0	0	0	0	20
1910	1	2	2	0	1	0	0	0	2	0	0	0	8
1911	0	0	0	0	0	0	0	0	0	0	1	4	5
1912	1	9	9	6	1	5	1	0	1	1	2	0	36

FORECASTING HIGH WATER AT AUGUSTA, GA.

When in 1888 a great freshet broke upon Augusta the muddy waters of the restless Savannah flowed through the streets of the city for the first time in nearly a quarter of a century and were of greater depth, velocity, and destructive force than at any time since the flood of 1796. Fear of the water had disappeared, and its full possibilities as a destroyer of life and property had become a mere tradition dimmed by the passing of many years.

The freshet of 1888, however, impressed upon the public mind a conviction of the necessity for some means of protection, and that there might be opportunity to safeguard life and movable property the Augusta district of the River and Flood Service of the Weather Bureau was organized in 1892 to give warning of the approach of dangerously high water.

Since 1892 there has accumulated a valuable series of daily rainfall observations for the Savannah River watershed above Augusta, and an earnest effort has been made to obtain from the data a scheme for the forecasting of river stages at Augusta as accurate and complete as can be devised. Since the rises are flashy, sometimes being very sudden, river-gage reading at points above are usually of little avail, and estimates must be based upon the relation between the average rainfall over the catchment basin and the stages normally resulting therefrom under the existing conditions. Such a scheme can not be expected to give absolutely accurate results in every instance, but tests have shown a degree of accuracy that meets every practical requirement.

Predictions of high-water stages have been made for Augusta for a number of years, and frequently with considerable accuracy and success, but in some instances the warnings preceded the flood crests by so few hours that their usefulness was greatly impaired. This feature was one of the first to receive my attention three years ago in my effort to make the work more effective, and it can be confidently stated that the possibility of the development of dangerous river conditions without ample and timely warning has been fully eliminated.

With 9 stations outside of Augusta telegraphing each inch of rain as it falls during the day, each half inch or more for the 24 hours ending at 8 a. m., and special reports whenever requested, the river forecaster is at all times in possession of the detailed information necessary for the proper performance of his duties. Additional security from surprise is afforded by placing nearly all of the instruments in the hands of telegraph operators, who can telegraph reports even at night if an emergency should require it.

Nearly all of the river forecasts are for the information of farmers, lumbermen, steamboat companies, and engineers and contractors engaged on Government or municipal developments along the river. Only on rare occasions does it become necessary to give warnings of stages dangerous to Augusta itself, but occasionally the river rises high enough to cause apprehension. Whether the desire for information is inspired by a prediction of actual danger or merely by a general fear of danger, every effort is made to secure and disseminate the most reliable information obtainable. Predictions are made for all stages above 18 feet.

Excellent opportunity during the past two years to observe the river under nearly all possible conditions has supplied much experience that was needed to point out some facts not made sufficiently clear by the abstract study of the records. This experience has indeed been so useful that it seems warrantable to complete the work of putting the forecast scheme in permanent form.

In the South, where snow and ice are almost unknown and never accumulate to any extent, the forecasting of high river stages from reports of precipitation is comparatively simple. The question in each instance resolves itself into the determination of the probable effect of the average rainfall over the watershed as indicated by telegraphic reports from selected stations.

The chief difficulty arises from varying absorption by the ground, according to its degree of dryness and the rate of rainfall. A very dry or only slightly moist soil often absorbs so much rain, even when the amount is considerable, that the immediate effect upon the river is negligible. General heavy downpours on dry ground might conceivably result in a rapid run-off of water and a consequent material rise in the river, but rains of this intensity usually come in the summertime and are characteristically so local that their simultaneous occurrence over all or a large portion of the catchment area, which embraces 7,294 square miles, is a very remote possibility. Freshets of magnitude take place in the Savannah River at Augusta only after the ground in the upper reaches of the stream has become saturated.

Water from the more distant portions of the watershed also complicates the problem, for when the rainfall covers two or more consecutive 24-hour periods on the second and subsequent days an allowance must be added for the volume from the distant streams. In summer another uncertainty is introduced by the erratic distribution of the showers of that season.

DEVELOPMENT OF THE RIVER FORECAST SCHEME.

It is intended to discuss first the effect upon the river at Augusta of rains falling within a 24-hour period, then the effect of rains extending into 48-hour and longer periods. This discussion is based for the most part on records for the 24 hours ending at 8 a. m., but in some cases when it was evident that the actual 24-hour rainfall covered the observation hour the records for two dates were combined.

It appears from the figures about to be set forth and the charts accompanying this paper, that neither the exact time of occurrence of rain at the various stations, nor the time and duration of the heaviest downpours, nor the distribution of the amounts at the various stations, is of great importance under ordinary circumstances in influencing the height ultimately reached by the water. All of these questions may in special instances become important, however, and it is on this account that observers are required to immediately report all heavy rainfall during the day.

Flood crests usually reach Augusta in from 18 to 30 hours after the receipt of the rainfall telegrams. The distribution of amounts has much to do with the rate of rise and the time of arrival of the crest of the rise, though, as has been intimated, it has little effect on the magnitude of the ultimate stage.

The averages given in the tables are based chiefly on rainfall measurements at seven points in the Savannah River watershed above Augusta, but during the first 10 years there were only six stations in operation much of the time. The seven stations for which most of the averages were computed are Augusta, Ga., Washington, Ga., Greenwood, S. C., Calhoun Falls, S. C., Carlton, Ga., Anderson, S. C., and Toccoa, Ga.

The consistency in the relation between the rainfall averages and the river stages in all but a few instances, demonstrates that the six or seven reports used give true averages for the watershed. To provide against the repetition of the few unreliable averages, however, additional stations were established in July, 1912, at Camak, Ga., Edgefield, S. C., and Gillsville, Ga. A balanced horizontal distribution of rainfall stations has always been maintained, with a somewhat greater number on the Georgia side on account of the greater number and greater importance of the tributaries there. River gage readings are reported from Carlton, Ga., on the Broad River, and Calhoun Falls, S. C., on the Savannah River.

Tables of importance in forecasting.

The natural supposition is that the higher the water in the river becomes the less will be the effect of a given portion of the total amount of rainfall in producing any further increase in depth. Beyond a certain river stage, which may be conservatively placed at 29 feet at Augusta, this is true of the Savannah River. When the soil is moist at the outset the normal rise from stages under 16 feet, remains near 8.5 feet for each inch of average rainfall over the watershed in 24 hours until the 29-foot stage is reached. In a few instances the rise for each inch of rain has exceeded 9 feet, but 8.5 feet gives an excellent working basis for forecasting purposes.

A partial explanation of this persistency of rise is, that the ground absorption reduces the rise at lower stages to such an extent as to counterbalance much of the retarding effect of the increasing width of the stream and the accelerated velocity of the current at higher stages. Additional explanation is found in the fact that the percentage of run-off from the faster rate of fall of larger amounts of rain is enough greater than the percentage of run-off from the slower rate of fall of the smaller amounts of rain, to materially assist in giving, for the larger amounts, the same average rise in feet per inch of rain, with high resultant stages, as results from smaller amounts with lower stages.

The following is the key to the Savannah River forecast scheme. In Table VI are given the results of a few rainfalls averaging less than an inch in 24 hours for the catchment area, the mean rise for such rains on moist soil being found to be 8.4 feet per inch of precipitation. In Tables VII and VIII, which contain all records from January 1, 1892, through April, 1912, the mean rise per inch of rain is found to be 8.7 feet for 24-hour rains of 1 to 1.50 inches, and 8.5 feet for rains of 1.51 to 2.50 inches. Table IX gives the results of heavier 24-hour rains on stages of 16 feet or less and indicates a value of about 3 feet for each inch of rain in excess of the amount

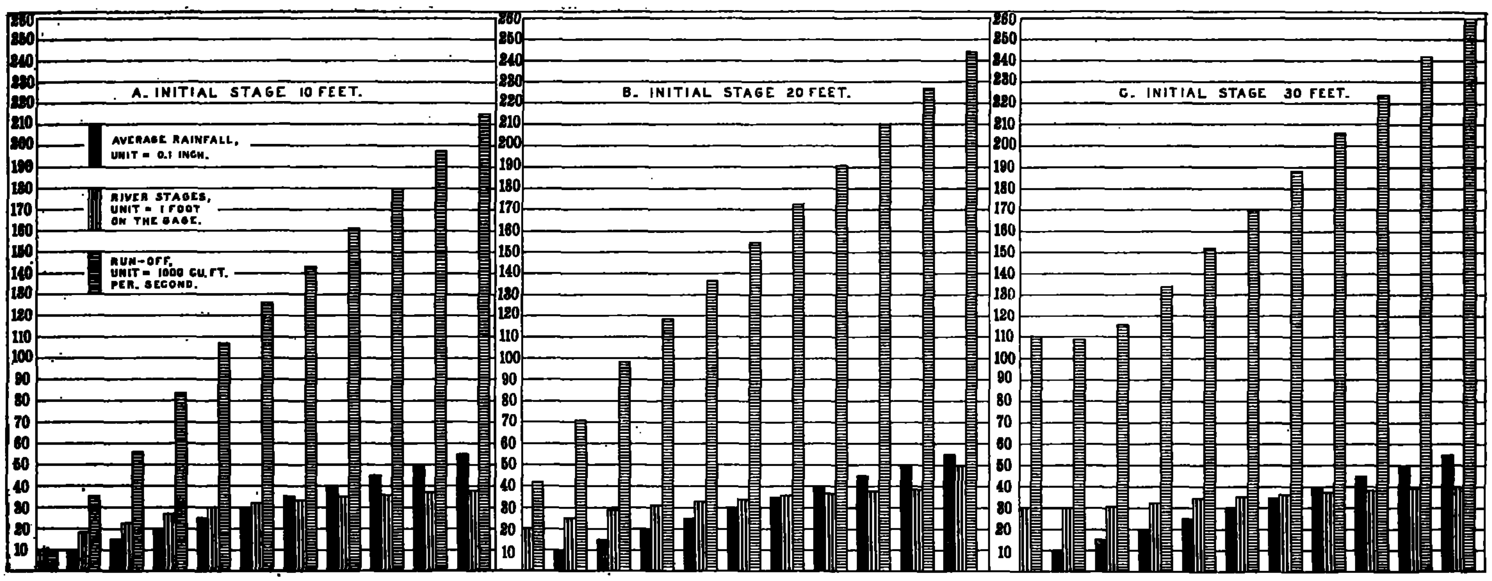

FIG. 3.—River forecast scheme. Diagram No. II. Relation of 24-hour rainfall over the Savannah River watershed to river stages, and run-off in cubic feet per second at Augusta, Ga. A. Initial stage 10 feet. B. Initial stage 20 feet. C. Initial stage 30 feet.

required to produce the 29-foot stage. All but one of the rainfall averages in this table are in excess of 3 inches, and the results in all but one instance are close to estimates based on the forecasting table. (Table XI.) The excessive rise of March 15, 1912, when the river reached 36.8 feet on the gage as against a maximum estimate of 35.1, resulted from the soil being entirely uncultivated. Persistent rains had prevented the usual winter plowing and left the hillsides completely saturated as well as hard and bare.

TABLE VI.—*Effect of 24-hour rains of less than 1 inch over the Savannah River watershed, on river stages below 16 feet at Augusta, Ga.*

[Estimated rise of 8.5 feet per average inch of rainfall.]

Date.	Average rainfall.	Initial stage.	Rise to highest stage.	Rise per inch of rain.	Estimated stage.	Highest stage.
	Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Dec. 20, 1892	0.80	9.1	6.4	8.0	15.9	15.5
Mar. 2, 1895	.87	8.9	8.8	9.4	16.3	17.2
Mar. 8, 1895	.96	10.5	7.4	7.7	18.7	17.9
Apr. 22, 1900	.80	10.3	5.2	6.5	17.1	15.5
Nov. 26, 1900	.90	7.2	7.0	6.5	14.8	14.2
Jan. 11, 1903	.61	9.0	5.2	8.5	14.2	14.2
Feb. 9, 1905	.95	8.5	9.3	9.8	16.6	17.8
Jan. 12, 1905	.80	10.5	5.5	6.9	17.3	16.0
Sept. 12, 1905	[1] .88	9.1	7.9	9.0	16.4	17.0
Mar. 2, 1907	.60	12.0	5.0	8.3	17.1	17.0
Mar. 7, 1909	.41	10.8	4.0	9.8	14.3	14.8
Mar. 25, 1909	.59	12.8	5.1	8.7	17.8	17.9
June 30, 1910	.68	10.3	5.9	8.7	16.1	16.2
Mean	.75	9.8		8.4		

[1] Reports covered two dates, but rain fell in 24 hours.

NOTE.—The above table embraces only a few illustrative examples.

TABLE VII.—*Effect of 24-hour rains of 1 inch to 1.50 inches over the Savannah River watershed, on river stages below 16 feet at Augusta, Ga.*

[Estimated rise of 8.5 feet per average inch of rainfall.]

Date.	Average rainfall.	Initial stage.	Rise to highest stage.	Rise per inch of rain.	Estimated stage.	Highest stage.
	Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Sept. 22, 1892	1.06	12.3	8.5	8.0	21.3	20.8
Feb. 28, 1893	1.24	8.9	12.1	9.8	19.4	21.0
Apr. 17, 1895	1.15	8.8	10.0	8.7	18.6	18.8
Dec. 15, 1896	1.30	7.3	10.3	7.9	18.3	17.6
Jan. 21, 1897	1.35	10.2	11.0	8.0	21.7	21.2
Feb. 12, 1897	[1] 1.40	12.1	10.8	7.7	24.0	22.9
Apr. 1, 1897	[1] 1.22	9.4	10.2	8.4	19.8	19.6
May 1, 1897	1.07	8.9	8.0	7.5	18.0	16.9
Aug. 21, 1897	[1] 1.12	12.0	8.4	7.5	21.5	20.4
Mar. 1, 1900	[2] 1.41	10.3	13.0	9.3	22.3	23.4
June 2, 1903	1.34	10.2	10.4	7.8	21.6	20.6
Mar. 7, 1904	1.05	8.1	9.5	9.0	17.0	17.6
Jan. 12, 1908	1.50	13.0	14.4	9.6	25.7	27.4
Apr. 27, 1908	1.26	12.3	11.7	9.3	23.0	24.0
Jan. 17, 1909	[1] 1.14	10.7	10.3	9.0	20.4	21.0
Mar. 10, 1909	1.40	12.8	13.9	9.9	24.7	25.7
Feb. 18, 1910	1.29	9.4	12.0	9.3	20.4	21.4
Feb. 24, 1910	[1] 1.02	15.2	9.1	8.9	23.9	24.3
Jan. 3, 1911	1.09	9.0	9.4	8.6	18.3	18.4
Feb. 22, 1912	[1] 1.10	13.2	11.1	10.0	22.6	24.3
Mar. 29, 1912	1.34	13.5	12.3	9.2	24.9	25.8
Mean	1.23	10.8		8.7		

[1] Reports covered two dates, but rain fell in 24 hours.
[2] Mean for 16 stations; 6 stations gave mean of 1.20 inches.

TABLE VIII.—*Effect of 24-hour rains of 1.51 to 2.50 inches over the Savannah River watershed, on river stages below 16 feet at Augusta, Ga.*

[Estimated rise of 8.5 feet per average inch of rainfall.]

Date.	Average rainfall.	Initial stage.	Rise to highest stage.	Rise per inch of rain.	Estimated stage.	Highest stage.
	Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Feb. 21, 1892	[1] 1.96	8.9	17.5	8.9	25.6	26.4
Apr. 8, 1895	1.62	8.8	13.9	8.6	22.6	22.7
Aug. 22, 1895	[1, 2] 2.56	8.6	21.9	8.6	30.4	30.5
Feb. 27, 1899	2.13	11.5	18.7	8.8	29.6	30.2
June 24, 1900	[1] 2.36	9.8	19.6	8.3	29.9	29.4
Feb. 4, 1901	[1] 2.05	9.4	17.9	8.7	26.9	27.3
Apr. 20, 1901	1.56	11.0	13.0	8.3	24.3	24.0
June 14, 1901	[1] 2.20	9.2	18.0	8.2	27.9	27.2
Dec. 15, 1901	1.53	8.5	13.7	9.0	21.5	22.2
Mar. 29, 1902	2.07	12.2	16.2	7.8	29.8	28.4
Feb. 17, 1903	[1] 1.68	14.6	15.3	9.1	28.9	29.9
Feb. 28, 1903	1.56	12.5	14.5	9.3	25.8	27.0
Dec. 21, 1905	[1] 2.23	8.8	19.5	8.7	27.8	28.3
Jan. 4, 1906	[1] 2.21	10.0	19.6	8.8	28.8	29.6
Jan. 23, 1906	[3] 2.21	9.8	19.3	8.7	28.6	29.1
Mar. 15, 1906	1.72	9.9	15.1	8.8	24.5	25.0
Dec. 14, 1907	1.76	9.9	13.7	7.8	24.9	23.6
Dec. 23, 1907	2.08	9.4	19.4	9.3	27.2	28.8
Dec. 30, 1907	[1] 1.65	13.0	15.0	9.1	27.0	28.0
Feb. 1, 1908	2.07	9.7	17.9	8.6	27.3	27.6
Feb. 10, 1908	2.14	10.3	17.8	8.3	28.5	28.1
Dec. 22, 1908	[1] 2.07	8.5	18.0	8.7	26.1	26.5
May 1, 1909	1.96	10.8	15.1	7.7	27.5	25.9
Jan. 29, 1910	[1] 1.55	9.8	12.1	7.8	23.0	21.9
Mar. 1, 1910	1.51	13.0	13.4	8.9	25.8	26.4
Feb. 15, 1912	2.27	10.2	19.7	8.7	29.5	29.9
Mar. 6, 1912	1.52	14.2	11.6	7.6	27.9	25.8
Means	1.93	10.4		8.5		

[1] Reports covered two dates, but rain fell in 24 hours.
[2] Slightly but not materially above limit of 2.50 inches in caption of table.
[3] Mean for 14 stations; 7 stations gave mean of 1.72 inches.

TABLE IX.—*Effect of 24-hour rains exceeding 2.50 inches over the Savannah River watershed, on river stages of 16 feet and below at Augusta, Ga.*

[Estimated rise based on values in Table XI.]

Date.	Average rain.	Initial stage.	Estimated rise per inch of rain.	Rise per inch of rain.	Rise per inch above 29 feet.[1]	Rise to highest stage.	Estimated stage.	Highest stage.
	Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Oct. 9, 1894	2.72	5.3	8.5	8.3		22.7	28.4	28.0
Mar. 26, 1901	3.14	8.7	7.4	6.7		21.1	31.8	29.8
Apr. 3, 1901	[2] 3.03	12.6	6.6	6.3	2.5	19.2	32.6	31.8
Feb. 28, 1902	[3] 3.21	16.5	5.5	5.6	3.2	18.1	34.3	34.6
Feb. 8, 1903	[2] 3.31	15.2	5.6	5.4	2.5	18.0	33.6	33.2
Mar. 15, 1912	[2] 3.75	13.9	5.7	6.1	[4] 4.0	22.9	35.1	[4] 36.8

[1] After allowing 8.5 feet per inch of rain to 29-foot stage.
[2] Reports covered two dates, but rain fell in 24 hours.
[3] Average for 15 stations; 7 gave an average of 3.01 inches.
[4] Soil thoroughly saturated and uncultivated.

Before attempting to construct a table on which shall be represented the stage to be expected from any possible rainfall on any possible initial stage (approximately maximum run-off conditions being assumed), it is necessary to consider rains that fall when the initial stage is already 16 feet or above. Although a glance at Table X is sufficient to show the impossibility of establishing a law of averages for any of its values, as was successfully done in the tables heretofore discussed, such individual results in this table as were consistent, similar data from other sources, and the averages in the first four tables, made possible the constructing of a forecasting table that is comprehensive and much more reliable than was thought possible when these studies were begun. Tests in practical river forecast work have demonstrated its accuracy in numerous instances when river stage and rainfall combinations were not matched by precedents, and established its superiority over the haphazard plan of searching voluminous records for precedents, or data as near precedents as may exist.

TABLE X.—*Effect of 24-hour rains over the Savannah River watershed, on river stages of 16 feet and over at Augusta, Ga.*

[Estimated rises based on values in Table XI.]

Date.	Average rain.	Initial stage.	Estimated rise per inch of rain.	Rise per inch of rain.	Rise to highest stage.	Estimated stage.	Highest stage.
	Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
July 11, 1892.	[1] 1.03	[2] 21.8	4.2	2.7	2.9	26.3	24.7
Aug. 6, 1894.	[1] 1.27	[2] 20.7	5.3	2.8	3.6	27.4	24.3
Mar. 16, 1895.	[1] 1.50	[2] 27.6	1.6	0.6	0.9	30.3	28.5
Feb. 9, 1896.	[3] 1.10	20.5	5.1	3.6	4.0	26.1	24.5
Mar. 13, 1897.	[1] 0.92	[2] 18.6	5.8	5.8	5.3	23.9	23.9
Apr. 5, 1897.	[1] 1.53	[1] 19.4	6.2	6.5	9.9	28.8	29.3
Apr. 21, 1900.	[1] 1.89	[2] 24.0	3.9	2.1	4.0	31.3	28.0
Aug. 28, 1901.	1.80	[2] 19.0	6.1	5.6	10.1	29.9	29.1
Feb. 11, 1903.	1.48	23.0	4.4	3.9	5.8	29.5	28.8
Mar. 23, 1903.	[1] 2.12	[2] 23.1	4.2	2.7	5.8	32.0	28.9
June 6, 1903.	[1] 1.35	[2] 18.1	6.7	6.8	9.2	27.2	27.3
Feb. 13, 1905.	[1] 1.09	[2] 22.3	4.0	3.2	3.5	26.7	25.8
Oct. 3, 1906.	0.95	17.6	6.4	6.5	6.2	23.7	23.8
Jan. 7, 1908.	1.39	15.8	7.9	6.5	9.0	26.8	24.8

[1] Includes 30 per cent of average rainfall in area above Calhoun Falls, S. C., reported at 8 a. m. of preceding date.
[2] Stage at 8 a. m. during rainfall covering more than one 24-hour period.
[3] Reports covered two dates but rain fell in 24 hours.

THE TABLE OF NORMAL RESULTANT STAGES.

After all known resultant stage values had been entered in a table along the side of which had been entered all stages from 8 feet to 36 feet and along the top each half-inch difference in rainfall from 1 to 5.50 inches, theoretical resultant stages were interpolated where possible and empirically estimated where interpolation was impossible. To test the general accuracy of the result and locate individual inaccuracies, the values were smoothed out by using the run-off equivalents for the various stages. The run-off equivalents in cubic feet per second for all stages from 10 to 40 feet, as furnished by the United States Geological Survey, were applied to the problem in hand, as shown in Tables XII and XIII. Only resultant stages opposite 5-foot intervals in initial stages were subjected to this test, and the intervening figures were interpolated.

All questions of doubt have been decided for the benefit of the public, and for the purpose of making estimates a little too high rather than too low. Thus, for example, although the 27 or 28-foot stage will sometimes carry off an inch of rain falling in a distinct 24-hour period after an interval between rains, yet the 29-foot stage has been assigned as the one to be expected to carry off an inch without further rise. It should be remembered, however, that the resultant stages indicated by the table are subject to increases in individual instances when unusually heavy run-off is anticipated.

TABLE XI.—*Stages normally resulting in the Savannah River at Augusta, Ga., from rainfall over the watershed, after deducting from average rainfall an allowance for ground absorption and after adding 30 per cent of previous day's average for upper section minus absorption.*

Initial stage.	Rainfall and resulting stages.									
	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50
8 feet	16.5	20.8	25.0	29.0	31.1	32.9	34.4	35.5	36.6	37.7
9 feet	17.5	21.8	26.0	29.5	31.4	33.1	34.5	35.7	36.8	37.8
10 feet	18.5	22.8	27.0	29.8	31.7	33.3	34.7	35.9	37.0	37.9
11 feet	19.5	23.8	28.0	30.2	32.0	33.5	34.9	36.1	37.2	38.1
12 feet	20.5	24.8	29.0	30.6	32.3	33.7	35.1	36.3	37.4	38.3
13 feet	21.5	25.8	29.4	31.0	32.7	34.1	35.4	36.5	37.6	38.5
14 feet	22.5	26.7	29.7	31.4	33.1	34.5	35.7	36.8	37.8	38.7
15 feet	23.0	27.5	30.0	31.8	33.5	34.9	36.0	37.1	38.0	38.9
16 feet	23.5	27.9	30.2	32.0	33.7	35.0	36.2	37.2	38.1	39.0
17 feet	24.0	28.2	30.4	32.2	33.9	35.1	36.3	37.3	38.2	39.1
18 feet	24.4	28.4	30.6	32.4	34.0	35.2	36.4	37.4	38.3	39.2
19 feet	24.8	28.6	30.8	32.6	34.1	35.3	36.5	37.5	38.4	39.3
20 feet	25.2	28.8	31.0	32.8	34.2	35.4	36.6	37.6	38.5	39.4
21 feet	25.6	29.1	31.2	32.9	34.4	35.6	36.7	37.7	38.6	39.5
22 feet	26.0	29.4	31.4	33.0	34.5	35.7	36.8	37.8	38.7	39.6
23 feet	26.4	29.6	31.6	33.1	34.6	35.8	36.9	37.9	38.8	39.7
24 feet	26.8	29.8	31.7	33.2	34.7	35.9	37.0	38.0	38.9	39.7
25 feet	27.2	30.0	31.8	33.4	34.9	36.0	37.1	38.0	38.9	39.7
26 feet	27.6	30.1	31.9	33.5	34.9	36.1	37.2	38.1	39.0	39.8
27 feet	28.0	30.2	32.0	33.6	35.0	36.1	37.2	38.1	39.0	39.9
28 feet	28.5	30.3	32.1	33.7	35.1	36.2	37.3	38.2	39.1	39.9
29 feet	29.0	30.5	32.2	33.9	35.2	36.3	37.4	38.3	39.2	40.0
30 feet	30.0	30.7	32.5	34.1	35.3	36.4	37.5	38.4	39.3	40.0
31 feet	31.0	31.6	33.1	34.6	35.8	36.9	37.9	38.8	39.6	40.2
32 feet	32.0	32.5	33.7	35.1	36.3	37.3	38.3	39.1	39.8	40.5
33 feet	33.0	33.4	34.3	35.6	36.7	37.7	38.7	39.4	40.0	40.7
34 feet	34.0	34.2	34.9	36.1	37.1	38.1	39.0	39.7	40.3	40.9
35 feet	35.0	35.0	35.5	36.5	37.5	38.5	39.3	40.0	40.6	41.2
36 feet	36.0	36.0	36.0	36.9	37.9	38.9	39.6	40.3	40.9	41.4

CORRECTIONS TO BE APPLIED TO TABLE XI AFTER THE AUGUSTA LEVEE IS BUILT.

[Furnished by Chief Engineer, River and Canal Commission, Augusta, Ga.]

Present reading.	Reading in levee.	Present reading.	Reading in levee.
	Feet.		*Feet.*
34 feet	34.0	38 feet	40.0
35 feet	35.6	39 feet	42.0
36 feet	36.9	40 feet	[1] 44.3
37 feet	38.3	41 feet	[1] 46.0

[1] Estimated.

TABLE XII.—*Discharge in cubic feet per second corresponding to river stages in the Savannah River at Augusta, Ga.*

[Furnished by the United States Geological Survey.]

River stage.	Discharge per second.	River stage.	Discharge per second.	River stage.	Discharge per second.	River stage.	Discharge per second.
	Cu. feet.		*Cu. feet.*		*Cu. feet.*		*Cu. feet.*
10 feet	10,000	18 feet	33,500	26 feet	76,100	34 feet	151,000
11 feet	12,200	19 feet	37,500	27 feet	83,500	35 feet	165,000
12 feet	14,600	20 feet	41,800	28 feet	91,500	36 feet	180,500
13 feet	17,200	21 feet	46,500	29 feet	100,000	37 feet	190,500
14 feet	20,000	22 feet	51,600	30 feet	109,000	38 feet	216,000
15 feet	23,000	23 feet	57,100	31 feet	118,500	39 feet	236,000
16 feet	26,300	24 feet	63,000	32 feet	128,500	40 feet	260,000
17 feet	29,800	25 feet	69,300	33 feet	139,500		

TABLE XIII.—*Increase in run-off in cubic feet per second at Augusta, Ga., resulting from 24-hour rainfall over the Savannah River watershed.*

Rain.	River stage.	Run-off per second.	Increase, run-off per second.	Rain.	River stage.	Run-off per second.	Increase, run-off per second.
Inches.	*Feet.*	*Cu. feet.*	*Cu. feet.*	*Inches.*	*Feet.*	*Cu. feet.*	*Cu. feet.*
	10.0	10,000			25.0	69,300	
0.50				0.50			
1.00	18.5	35,500	25,500	1.00	27.2	85,000	15,800
1.50	22.8	56,000	20,500	1.50	30.0	109,000	24,000
2.00	27.0	83,500	27,500	2.00	31.8	127,000	18,000
2.50	29.8	107,200	23,700	2.50	33.4	145,000	18,000
3.00	31.7	125,200	18,000	3.00	34.9	163,000	18,000
3.50	33.3	143,200	18,000	3.50	36.0	181,000	18,000
4.00	34.7	161,200	18,000	4.00	37.1	199,000	18,000
4.50	35.9	179,200	18,000	4.50	38.0	217,000	18,000
5.00	37.0	197,200	18,000	5.00	38.9	235,000	18,000
5.50	37.9	215,200	18,000	5.50	39.7	253,000	18,000
	15.0	23,000			30.0	109,000	
0.50				0.50			
1.00	23.0	57,100	34,100	1.00	30.0	109,000	00,000
1.50	27.5	87,500	30,400	1.50	30.7	116,000	7,000
2.00	30.0	109,000	21,500	2.00	32.5	134,000	18,000
2.50	31.8	127,000	18,000	2.50	34.7	152,000	18,000
3.00	33.5	145,000	18,000	3.00	35.3	170,000	18,000
3.50	34.9	163,000	18,000	3.50	36.4	188,000	18,000
4.00	36.0	181,000	18,000	4.00	37.5	206,000	18,000
4.50	37.1	199,000	18,000	4.50	38.4	224,000	18,000
5.00	38.0	217,000	18,000	5.00	39.3	242,000	18,000
5.50	38.9	235,000	18,000	5.50	40.0	260,000	18,000
	20.0	41,800			35.0	165,000	
0.50				0.50			
1.00	25.2	70,700	28,900	1.00	35.0	165,000	00,000
1.50	28.8	98,300	27,600	1.50	35.0	165,000	00,000
2.00	31.0	118,500	20,200	2.00	35.5	175,000	10,000
2.50	32.8	136,500	18,000	2.50	36.5	189,000	14,000
3.00	34.2	154,500	18,000	3.00	37.5	207,000	18,000
3.50	35.4	172,500	18,000	3.50	38.5	225,000	18,000
4.00	36.6	190,500	18,000	4.00	39.3	243,000	18,000
4.50	37.6	208,500	18,000	4.50	40.0	261,000	18,000
5.00	38.5	226,500	18,000	5.00	40.6	279,000	18,000
5.50	39.4	244,500	18,000	5.50	41.2	297,000	18,000

TABLE XIV.—*Normal rise in the Savannah River at Augusta, Ga., per average inch of rainfall over the watershed, in 24 hours, when the soil is moist.*

[Values derived from Table XI.]

Initial stage.	Rainfall, inches, and Rise in feet per inch of rain.									
	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50
8 feet	8.5	8.5	8.5	8.4	7.7	7.1	6.6	6.1	5.7	5.4
9 feet	8.5	8.5	8.5	8.2	7.5	6.9	6.4	5.9	5.6	5.2
10 feet	8.5	8.5	8.5	7.9	7.2	6.7	6.2	5.8	5.4	5.1
11 feet	8.5	8.5	8.5	7.7	7.0	6.4	6.0	5.6	5.2	4.9
12 feet	8.5	8.5	8.5	7.4	6.8	6.2	5.8	5.4	5.1	4.8
13 feet	8.5	8.5	8.2	7.2	6.6	6.0	5.6	5.2	4.9	4.6
14 feet	8.5	8.5	7.8	7.0	6.4	5.9	5.4	5.1	4.8	4.5
15 feet	8.0	8.3	7.5	6.7	6.2	5.7	5.2	4.9	4.6	4.3
16 feet	7.5	7.8	7.1	6.4	5.9	5.4	5.0	4.7	4.4	4.2
17 feet	7.0	7.5	6.7	6.1	5.6	5.2	4.8	4.5	4.2	4.0
18 feet	6.4	7.0	6.3	5.8	5.3	4.9	4.6	4.3	4.1	3.9
19 feet	5.8	6.4	5.9	5.4	5.0	4.7	4.4	4.1	3.9	3.7
20 feet	5.2	5.9	5.5	5.1	4.7	4.4	4.2	3.9	3.7	3.5
21 feet	4.6	5.4	5.1	4.8	4.5	4.2	3.9	3.7	3.5	3.4
22 feet	4.0	4.9	4.7	4.4	4.2	3.9	3.7	3.5	3.3	3.2
23 feet	3.4	4.4	4.3	4.0	3.9	3.7	3.5	3.3	3.2	3.0
24 feet	2.8	3.9	3.8	3.7	3.6	3.4	3.2	3.1	3.0	2.9
25 feet	2.2	3.3	3.4	3.3	3.3	3.1	3.0	3.0	2.8	2.7
26 feet	1.6	2.7	3.0	3.0	3.0	2.9	2.8	2.7	2.6	2.5
27 feet	1.0	2.1	2.5	2.6	2.7	2.6	2.5	2.5	2.4	2.3
28 feet	0.5	1.5	2.0	2.3	2.4	2.3	2.3	2.3	2.2	2.2
29 feet	0.0	1.0	1.6	2.0	2.1	2.1	2.1	2.1	2.0	2.0
30 feet	0.0	0.5	1.2	1.6	1.8	1.8	1.9	1.9	1.9	1.8
31 feet	0.0	0.4	1.0	1.4	1.6	1.7	1.7	1.7	1.7	1.7
32 feet	0.0	0.3	0.8	1.2	1.4	1.5	1.6	1.6	1.6	1.5
33 feet	0.0	0.3	0.6	1.0	1.2	1.3	1.4	1.4	1.4	1.4
34 feet	0.0	0.1	0.4	0.8	1.0	1.2	1.2	1.3	1.3	1.3
35 feet	0.0	0.0	0.2	0.6	0.8	1.0	1.1	1.1	1.1	1.1
36 feet	0.0	0.0	0.0	0.4	0.6	0.8	0.9	1.0	1.0	1.1

ABSORPTION OF MOISTURE BY THE SOIL.

Absorption varies with ground conditions as to moisture and cultivation, and with rate of rainfall. Slowness of rain on moist or even wet soil causes large reductions from the surface run-off, and on loose soil that is either dry or only slightly moist such rain will be almost entirely absorbed. Heavy rain on any kind of soil has a relatively high percentage of run-off, particularly in a hilly country such as that in the Savannah watershed.

It is occasionally commented upon by those familiar with the peculiarities of the river, that with similar rainfall a greater rise often occurs from very dry soil than from soil previously dampened by precipitation after a long dry spell. This discloses an interesting truth regarding the absorption of moisture by the soil. As Widtsoe, in "Dry Farming," expresses it, "very dry soil and moisture repel each other." The principle is illustrated by the familiar experiment of placing a dry sponge and moist sponge in water at the same time. The moist sponge is instantly saturated, while the dry one takes in the water slowly at first and is not saturated for some little time.

From measurements made by the Bureau of Plant Industry, it appears that excessive precipitation should give a heavier surface run-off from the dust mulch land of late spring and early summer than from the dry laid-by land of late summer and early autumn. L. J. Briggs and J. O. Belz, in Bureau of Plant Industry Bulletin No. 188, report measurements in Utah which show that during a heavy rain of 2.5 inches in four hours, summer-tilled land was so quickly packed by the force of the downpour that it absorbed only 0.5 inch, or 20 per cent of the water, while adjacent wheat-stubble land which was dry and contained many surface cracks, absorbed 1.5 inches, or 60 per cent. From other experiments reported by the same writers it appears that this loss of 80 per cent on tilled land is an extreme case, but the flow would be heavier from the slopes of the Savannah Valley farms than from the level land on which the reported experiments were made.

Many rains averaging more than an inch for the watershed are negligible so far as the forecasting of river stages of 18 feet and over is concerned. Averages, especially in warm weather, must usually be subjected to reductions of from 0.25 inch to 1 inch before being carried to the above given forecasting table. When an additional reduction must be allowed in the estimated rise on account of erratic distribution of summer showers it is often found to be unnecessary to make an official prediction on rains that if distributed generally would give a high stage.

On the morning of September 23, 1897, the rainfall reports averaged 2.22 inches of rain, which had fallen at a steady rate for nearly 24 hours on very dry soil. The resulting rise in the Savannah at Augusta was equivalent to the theoretical rise on only 0.92 inch of rain. The 2.51 inches of rainfall reported June 13, 1906, produced only such a rise as would follow 1.46 inches of rain falling at a normal rate on moist soil. Thus it is seen that heavy rains falling at a steady rate may be largely absorbed by a thirsty soil.

To attempt to lay down fixed rules for allowances to be made for ground absorption would be useless. A little experience and the knowledge and trained judgment of a person familiar with meteorological work are essential. Much depends upon the season of the year, the character of the weather as to temperature, cloudiness, wind, and light rains, and the condition of the soil as to cultivation. The records should be carefully studied by the forecaster. Table XV and diagrams on file at Augusta are designed to supplement a careful perusal of the daily records. It has been found that the river gage readings at Carlton, Ga., and Calhoun Falls, S. C., are sometimes helpful.

It may be well to comment at this point on the fact that deficient river rises from slow rainfall on saturated soil are followed by gradual return to normal stages. Occasionally this delayed run-off, which is probably partly surface flow and partly groundwater flow, combines with the rise from rains a day or two later and gives a stage somewhat higher than would otherwise occur. In a few instances it has been sufficiently pronounced to delay by as much as 24 hours the highest stage following a 24-hour rain. In such cases the crest agrees closely with that indicated by the forecast table, a deficient 24-hour rise being augmented by the delayed run-off.

EFFECT OF RAINFALL DISTRIBUTION ON THE HEIGHT OF THE FLOOD CREST.

In selecting stations that are to report rainfall for river-stage forecasting it is of the utmost importance to maintain at all times a consistent horizontal distribution. This does not mean that the stations should be equidistant, for in such an arrangement the drainage areas of major importance would be given the same weight as relatively insignificant areas. Over basins drained by larger and more numerous streams more stations should be placed than over those of lesser importance in accumulating and discharging the surface run-off from rainfall. This work properly and thoroughly done disposes of the question of rainfall distribution so far as the importance of one station over another is concerned and incidentally eliminates from the problem all consideration of topography and other physical peculiarities of a permanent character.

When it is stated that the drainage basin of the Savannah River above Augusta must be divided into two sections, from one of which the crest reaches Augusta in from 18 to 24 hours and from the other in about 40 to 48 hours, it is at first difficult to see why the stations in the section above Calhoun Falls should be given the same individual weight in computing the rise to be expected from a 24-hour rain as are the stations over the area from which the crest reaches Augusta in much less time. However, experimental forecasts in which the upper stations are ignored nearly always result in a decided loss of accuracy.

It appears that the run-off from heavy rains in the upper section of the watershed supports the water in the neighboring portions of the streams, and, by preventing it from flattening out, contributes indirectly to the ultimate stage. When there is no such support, the maximum stage at Augusta is lower in proportion to the deficiency of precipitation in the upper section. When precipitation is decidedly heavier in the upper section than in the lower, its volume is sometimes sufficient to continue the rise beyond the usual time and give a crest higher than that indicated by the average rainfall for the watershed. Such an occurrence is somewhat rare, but it may be anticipated by adding to the average for all stations 30 per cent of the difference between the average for the upper stations and the average for all stations.

From what has been said it is obvious that when general rain falls over the Savannah Valley the stage to be predicted can be determined without applying to the average rainfall any modification other than an allowance for absorption by the ground. This is true even though there be wide differences in the amounts at the various stations.

Frequently, however, summer showers do not distribute themselves generally over the watershed, and the run-off from wide areas may be either insignificant or entirely lacking. They follow no rule such as has been explained for general rainfall, and it is always necessary to determine as nearly as possible to what extent the distribution is erratic.

When the rains have fallen long enough before the receipt of the reports for the water to have taken effect at Carlton and Calhoun Falls, the river readings at those points are very helpful. It has also been found of assistance to utilize the reports from cotton region reporting stations. A knowledge of general meteorological conditions as shown by the daily weather map and an understanding of the significance of those conditions are required.

The above-mentioned aids in determining the character of the distribution are, however, merely supplementary to the following rules, which have been ascertained by practical experience, though the river-gage relations are often of almost equal importance and are sometimes the main deciding factor.

These rules are applicable only to erratic summer thunderstorms.

1. When the average rainfall is 2 inches it is very rarely advisable to reduce the estimate on account of irregularities in distribution.

2. When the rainfall averages 1.50 inches or somewhat less:

(*a*) When only 2 stations in 10 have less than 0.50 inch the distribution should be considered general and no allowance made for erratic distribution.

(*b*) When 3 stations in 10 have less than 0.50 inch allow three-fourths to full value, after making allowance for ground absorption.

(*c*) When 4 or 5 stations in 10 have less than 0.50 inch allow for a rise of only one-half value, unless 2 or more of the other stations have 3 or more inches of rain, when the estimate should be three-fourths to full value, in the discretion of the forecaster, after making allowance for ground absorption.

Before closing the subject of rainfall distribution it may be well to mention the fact that when one or two stations in the upper section of the watershed report 3.50 to 5 inches of rain that is apparently local in character the heavy downpours are at times of sufficient extent to cause a moderate rise that culminates in Augusta in 40 to 48 hours. In order to anticipate such rises, it is necessary to have the river stations report stages at 5 p. m. and the next 8 a. m.

TABLE XV.—*Effect of ground absorption and slow and erratic run-off on the relation between 24-hour rains and river stages at Augusta, Ga.*

[Normal rise per inch of rain, 8.5 feet.]

Date.	Average rain.	Absorption, etc.	Initial stage.	Normal rise.	Actual rise.	Highest stage.	Condition of soil.	Character of rain.
	Inches.	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*		
May 3, 1893....	1.12	0.57	7.6	9.5	4.8	12.4	Dry...	Showers.
Oct. 13, 1893...	1.82	.35	6.3	15.5	12.5	18.8	...do...	Steady.
Sept. 18, 1894...	1.14	.21	5.8	9.7	7.9	13.7	...do...	Slow.
Nov. 3, 1894....	1.28	.30	7.0	10.9	8.3	15.3	...do...	Showers.
Jan. 17, 1896....	1.63	.45	6.5	13.8	10.2	16.7	...do...	Steady.
Feb. 6, 1896....	1.56	.30	12.0	13.3	10.7	22.7	Moist.	Do.
Jan. 14, 1897....	1.28	.50	5.8	10.9	6.6	12.4	Dry...	Do.
Feb. 2, 1897....	1.18	.15	7.2	10.0	8.8	16.0	Moist.	Do.
Feb. 6, 1897....	2.31	.45	11.6	19.4	15.9	27.5	...do...	Do.
July 18, 1897...	1.91	.65	5.7	16.2	10.9	16.6	Dry...	Do.
Sept. 23, 1897...	2.22	1.30	4.5	18.9	8.0	12.5	...do...	Do.
Nov. 27, 1897...	1.25	.85	5.0	12.6	3.6	8.6	...do...	Do.
Apr. 5, 1898....	1.82	.65	8.5	15.5	10.0	18.5	Moist.	Do.
Apr. 24, 1898...	1.06	.50	6.8	9.0	5.0	11.8	...do...	Do.
Jan. 11, 1899...	0.90	.50	12.8	7.6	4.4	17.2	...do...	Slow.
Mar. 31, 1899...	0.99	.27	13.5	8.4	6.1	19.6	...do..	Showers.
July 27, 1899...	0.95	.36	7.0	8.1	5.7	12.7	Dry...	Steady.
Aug. 30, 1899...	1.18	.93	9.2	10.0	2.2	11.4	Wet...	Showers.
Mar. 16, 1900...	1.20	.30	10.0	10.2	7.8	17.8	Moist.	Steady.
June 17, 1900...	1.45	.47	11.5	12.3	8.3	19.8	...do...	Showers.
July 30, 1900...	1.19	.87	11.0	10.1	2.7	13.7	...do...	Steady.
Feb. 9, 1901....	0.90	.45	12.5	7.6	3.6	16.1	...do...	Do.
June 7, 1901....	1.35	.56	9.7	11.5	6.7	16.4	Dry...	Showers.
June 16, 1902...	1.83	1.08	9.5	15.6	6.4	15.9	...do...	Do.
July 14, 1903...	1.54	1.00	9.7	13.1	4.6	14.3	...do...	Do.

TABLE XV.—*Effect of ground absorption and slow and erratic run-off on the relation between 24-hour rains and river stages at Augusta, Ga.*—Con.

Date.	Average rain.	Absorption, etc.	Initial stage.	Normal rise.	Actual rise.	Highest stage.	Condition of soil.	Character of rain.
	Inches.	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*		
Jan. 23, 1904....	1.28	0.60	7.3	10.9	5.7	13.0	Dry...	Showers.
Dec. 3, 1905....	2.50	.85	6.0	21.2	13.9	19.9	...do...	Steady.
Dec. 9, 1905....	1.79	.60	8.6	15.2	10.2	18.8	Moist.	Slow.
May 7, 1906....	1.12	.70	9.0	9.5	3.7	12.7	Dry...	Do.
May 27, 1906...	1.30	.74	8.2	11.0	4.8	13.0	...do...	Showers.
June 13, 1906...	2.51	1.05	8.8	21.3	12.2	21.0	...do...	Steady.
July 9, 1906....	1.36	.35	10.0	11.6	8.5	18.5	...do...	Showers.
July 15, 1906...	1.69	.28	9.1	14.4	12.0	21.1	Moist.	Do.
July 30, 1906...	1.07	.22	10.8	9.4	7.2	18.5	Dry...	Do.
Apr. 23, 1907...	1.73	.38	8.0	14.7	11.5	19.5	...do...	Steady.
June 1, 1907....	1.20	.35	7.8	10.2	7.2	15.0	...do...	Showers.
June 28, 1907...	1.57	.78	7.5	13.3	6.7	14.2	Moist.	Steady.
Sept. 23, 1907...	1.49	.32	5.9	12.7	9.9	15.8	Dry...	Showers.
Mar. 21, 1908...	1.17	.65	9.5	9.9	4.3	13.8	Moist.	Steady.
June 15, 1908...	1.00	.53	8.8	8.5	4.0	12.8	Dry...	Showers.
Nov. 14, 1908...	1.11	.65	8.6	9.4	3.8	12.4	Moist.	Steady.
Aug. 3, 1909....	1.76	.54	10.1	15.0	10.4	20.5	...do...	Showers.
Sept. 18, 1909...	1.06	.58	14.9	9.0	3.9	18.8	...do...	Do.
Oct. 15, 1909...	1.43	.44	8.3	12.2	8.6	16.9	Dry...	Do.
Apr. 17, 1910...	1.76	.95	8.2	15.0	7.0	15.2	...do...	Steady.
Oct. 8, 1910....	2.04	1.20	10.9	17.3	7.2	18.1	...do...	Do.
Mar. 27, 1911...	1.14	.45	7.5	9.7	6.0	13.5	...do...	Do.
Apr. 8, 1911....	1.02	.58	13.2	8.7	4.6	17.8	Moist.	Showers.
July 14, 1911...	1.23	.62	8.4	9.4	5.2	13.6	Dry...	Do.
Oct. 22, 1911..	1.58	.75	8.5	13.4	6.9	15.4	Moist.	Slow.
Oct. 28, 1911...	1.47	.62	8.7	12.5	7.2	15.9	...do...	Steady.
Nov. 7, 1911...	1.10	.35	7.0	9.4	6.5	13.5	...do...	Do.
Nov. 9, 1911....	1.49	.60	13.5	12.7	7.1	20.6	Wet...	Slow.
Jan. 9, 1912....	1.26	.25	10.8	10.7	8.4	19.2	...do...	Steady.
Jan. 30, 1912....	1.97	.32	9.2	16.7	14.0	23.2	...do...	Do.

EXTENSION OF THE RIVER FORECAST SCHEME BEYOND ONE 24-HOUR PERIOD.

When rain occurs on two or more successive days it is necessary on the second and subsequent days to add to the average rainfall for all of the stations 30 per cent of the average reported from the upper section on the previous day. When it is necessary to make allowances for ground absorption and for erratic run-off, such allowances should be applied to the averages before any other computations are attempted. To determine the average for the upper section the rainfall measurements for Calhoun Falls, S. C., Carlton, Ga., Anderson, S. C., Gillsville, and Toccoa, Ga., are used.

The application of the rule in practice is exemplified in Table XVI, in which computations are given for all long rains that have resulted in stages of 25 feet or over since the beginning of the record in 1892. Through good fortune, averages for four excellently distributed stations are also available for the 1888 freshet, the stations being Augusta, Ga., Washington, Ga., Greenwood, S. C., and Toccoa, Ga.

The following comments and rules are of utmost importance in handling river forecast work at Augusta:

1. When more rain is expected to fall during the day, from 1 to 3 feet may be added to the estimate based on the morning reports, but when the river is above 15 feet or when there is a possibility of general heavy rains, special observations should be telegraphed from all stations at 2 p. m. or 5 p. m., or both. At times the river responds so quickly to the rainfall that it is no easy matter, even by the liberal use of special observations, to make a forecast that shall be both timely and accurate.

2. It is important to distinguish between rains occurring in two separate 24-hour periods and those falling within 24 hours though partly before and partly after 8 a. m. A compromise is occasionally advisable, especially when the rainfall is continuous.

3. The first estimate should always be based on the initial stage, i. e., the stage before the rains under consideration began to affect the river, even though there is already a considerable increase in the river stage.

4. When rainfall reports are received for an additional 24-hour period and the river stage is lower than indicated by the rainfall reports of the previous morning, base the forecast on the 8 a. m. stage, unless there is reason to believe the rise from the rains reported the previous morning has not approximately reached its crest.

5. When the 8 a. m. stage exceeds the estimate based on the reports of the previous morning, and the excess rise *can not* be charged to the effect of the rains represented by the current reports, use the 8 a. m. stage as the basis of the estimate.

6. When the 8 a. m. stage exceeds the estimate based on the reports of the previous morning and the excess rise *is* chargeable to the rains represented by the current reports, use as the basis of estimate the theoretical stage indicated by the reports of the previous morning.

7. When handling special rainfall reports, i. e., reports of observations taken at any other hour than 8 a. m., it is usually advisable to add to the average of the special reports 30 per cent of the 8 a. m. average for the upper section of the watershed and base the computation on the theoretical estimate resulting from the 8 a. m. reports. It is, however, sometimes better to consider the rain during the interval between 8 a. m. and the hour of the special observation a continuation of the rains reported at 8 a. m. and treat the sum of the two averages as rainfall within 24 hours. A compromise between these two methods may be resorted to in case of doubt.

TABLE XVI.—*Effect of rainfall over the watershed in two or more 24-hour periods on Savannah River stages at Augusta, Ga.*

[Estimates of rise based on Table XI after deducting allowances for ground absorption and slow and erratic run-off from rainfall averages.]

Date.	Average rain.	Absorption, etc.	Plus 30 per cent last upper.	Average, upper section.	Initial stage.	Stage at 8 a. m.	Estimated stage.	Highest stage.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Sept. 9, 1888.......	2.34	0	....	1.40	23.0	23.5	32.7	....
Sept. 10, 1888......	3.98	0	4.40	1.46	....	34.7	[1] 39.2	38.7
Jan. 18, 1892.......	1.43	.19	....	1.04	17.0	17.0	26.2	....
Jan. 19, 1892.......	1.45	0	1.76	2.03	....	26.2	31.0	....
Jan. 20, 1892.......	0.94	0	1.55	0.87	....	31.0	31.8	32.8
Mar. 24, 1892.......	0.52	0	....	0.29	8.3	8.3	12.7	....
Mar. 25, 1892.......	0.57	0	0.66	0.36	....	13.9	[1] 18.3	....
Mar. 26, 1892.......	1.76	.53	1.34	1.51	....	18.8	27.1	26.6
Feb. 12, 1893.......	0.81	0	....	0.67	9.8	9.8	16.7	....
Feb. 13, 1893.......	1.03	0	1.23	1.92	....	19.2	[1] 25.8	25.4
Dec. 11, 1894.......	0.71	.53	0.95	1.04	6.5	6.5	10.1	....
Dec. 12, 1894.......	1.84	0	1.99	2.57	....	10.1	27.0	26.2
Jan. 9, 1895.......	1.47	.50	....	1.57	7.7	9.3	15.9	....
Jan. 10, 1895.......	2.57	.30	2.09	1.90	....	25.0	[1] 30.5	30.5
Mar. 13, 1895.......	0.85	0	....	0.79	11.6	11.6	18.8	....
Mar. 14, 1895.......	0.74	0	0.98	0.90	....	22.5	[1] 24.8	....
Mar. 15, 1895.......	0.99	0	1.24	0.85	....	27.0	[1] 28.5	....
Mar. 16, 1895.......	1.24	.50	1.00	0.96	....	27.6	28.3	28.5
July 7, 1896.......	1.89	1.00	....	1.60	6.3	8.8	13.9	....
July 8, 1896.......	3.34	1.82	2.00	1.88	....	22.4	[1] 29.2	....
July 9, 1896.......	1.59	0	1.61	1.16	....	29.2	30.9	[2] 30.5
Mar. 12, 1897.......	0.79	0	....	1.24	11.2	11.2	17.9	....
Mar. 13, 1897.......	0.55	0	0.92	0.04	....	18.6	23.9	....
Mar. 14, 1897.......	0.98	0	....	1.15	....	23.9	26.6	25.6
Apr. 4, 1897.......	0.35	.35	....	0.57	17.7	17.7	17.7	....
Apr. 5, 1897.......	1.45	0	1.52	1.80	....	19.4	28.4	29.3
Sept. 1, 1898.......	1.84	0	....	2.17	15.3	15.3	29.3	[3] 29.0
Sept. 2, 1898.......	1.99	1.55	1.09	2.94	[3] 28.4	28.4	29.0	29.0

[1] Estimated rise based on theoretical estimate from rainfall reported at 8 a. m. of the previous day.

[2] A 30-foot stage was predicted on July 8, 1896, and seems to have been conservative. Shortage probably due to extremely erratic distribution of rain.

[3] River rose to 29 feet in early morning of Sept. 2, 1898, fell to 28.4 at 8 a. m., and rose to 29 feet on the 3d.

TABLE XVI.—*Effect of rainfall over the watershed in two or more 24-hour periods on Savannah River stages at Augusta, Ga.*—Continued.

Date.	Average rain.	Absorption, etc.	Plus 30 per cent last upper.	Average, upper section.	Initial stage.	Stage at 8 a. m.	Estimated stage.	Highest stage.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Feb. 5, 1899	0.66	0.25	....	0.77	14.5	14.5	18.8	....
Feb. 6, 1899	0.80	.25	0.71	1.12	....	20.8	[1] 22.9	....
Feb. 7, 1899	1.92	0	2.18	1.55	....	28.0	[1] 32.1	31.0
Feb. 10, 1900	0.71	0	....	0.61	8.4	8.4	14.4	....
Feb. 11, 1900	0.87	0	1.05	0.91	....	19.5	[1] 23.1	....
Feb. 12, 1900	1.50	.44	1.33	1.50	....	26.6	[1] 28.5	....
Feb. 13, 1900	1.84	0	2.16	2.16	....	28.5	32.7	32.7
Apr. 18, 1900	0.89	.50	....	0.95	9.0	9.0	12.3	....
Apr. 19, 1900	1.72	0	1.86	1.17	....	22.2	[1] 26.1	....
Apr. 20, 1900	0.95	.50	0.80	0.64	....	25.3	26.9	....
Apr. 21, 1900	1.70	.54	1.20	1.95	....	24.0	28.0	28.0
May 19, 1901	0.89	.75	....	0.93	8.4	8.4	9.6	....
May 20, 1901	1.27	.50	0.82	0.84	....	12.2	[1] 16.6	....
May 21, 1901	1.13	.50	0.73	1.14	....	19.8	[1] 21.7	....
May 22, 1901	1.79	.72	1.26	2.49	....	23.6	[1] 27.7	27.7
Sept. 17, 1901	1.53	1.00	....	2.23	9.0	9.0	13.5	....
Sept. 18, 1901	2.99	.77	2.59	2.78	....	23.4	[1] 31.6	31.6
Dec. 28, 1901	0.71	0	....	0.48	9.3	10.5	15.3	....
Dec. 29, 1901	[4] 1.76	0	1.90	[4] 2.37	....	14.1	29.2	31.0
Jan. 31, 1902	0.70	.37	....	0.72	11.4	11.4	14.2	....
Feb. 1, 1902	1.31	0	1.41	1.33	....	14.2	26.2	....
Feb. 2, 1902	1.86	0	2.26	1.75	....	28.0	[1] 32.7	32.6
Mar. 16, 1902	[4] 1.18	0	....	0.84	13.3	14.6	23.3	....
Mar. 17, 1902	1.04	0	1.29	0.91	....	27.2	[1] 28.4	27.5
Mar. 21, 1903	0.73	.50	....	0.75	11.6	11.6	13.6	....
Mar. 22, 1903	0.98	.25	0.80	1.00	....	16.5	[1] 20.4	....
Mar. 23, 1903	1.82	.30	1.74	2.17	....	23.1	30.0	....
Mar. 24, 1903	....	....	....	....	....	28.9	....	30.0
Mar. 29, 1903	0.75	.50	....	0.86	14.5	14.5	16.6	....
Mar. 30, 1903	1.82	.49	1.44	2.29	....	23.5	[1] 27.6	27.6
June 5, 1903	1.12	.52	....	1.47	13.0	13.0	18.1	....
June 6, 1903	1.07	0	1.35	1.23	....	18.1	27.2	27.3
Aug. 8, 1904	2.84	.99	....	3.41	8.3	14.0	24.0	....
Aug. 9, 1904	0.59	.59	0.58	0.62	....	23.2	[1] 25.6	25.5
Feb. 12, 1905	0.89	0	....	0.79	16.9	16.9	23.1	....
Feb. 13, 1905	0.85	0	1.09	0.36	....	22.3	26.7	25.8
Mar. 19, 1906	0.88	.25	....	1.36	13.8	13.8	19.2	....
Mar. 20, 1906	1.22	0	1.55	1.27	....	24.6	[1] 28.9	28.6
Feb. 10, 1908	0.80	0	....	0.86	11.0	11.0	17.8	....
Feb. 11, 1908	1.01	0	1.27	0.82	....	21.0	[1] 26.5	25.8
Mar. 23, 1908	1.10	0	....	1.17	14.0	14.0	23.4	....
Mar. 24, 1908	1.40	0	1.75	1.15	....	23.0	30.6	29.7
Aug. 24, 1908	2.23	.96	....	3.08	11.5	11.9	22.3	....
Aug. 25, 1908	2.82	0	3.45	3.93	....	22.3	35.4	....
Aug. 26, 1908	2.61	0	3.79	3.42	....	34.4	38.8	38.8
Feb. 22, 1909	0.78	0	....	1.06	13.6	13.6	20.2	....
Feb. 23, 1909	0.93	0	1.25	0.82	....	21.0	[1] 27.1	26.4
Mar. 12, 1909	[5] 0.68	0	....	0.39	23.0	23.0	23.0	....
Mar. 13, 1909	1.09	0	....	0.96	....	26.7	[1] 26.7	....
Mar. 14, 1909	0.64	0	0.93	0.79	....	26.7	27.6	28.0
June 3, 1909	1.74	.65	....	2.33	10.8	10.8	20.0	....
June 4, 1909	1.89	.89	1.50	2.12	....	23.5	[1] 28.7	28.7
Dec. 21, 1911	1.03	.22	....	1.07	9.4	11.8	16.3	....
Dec. 22, 1911	[4] 2.80	.63	[6] 2.17	2.72	....	16.3	31.5	31.5
Apr. 21, 1912	1.05	1.05	....	0.66	16.8	17.1	17.1	....
Apr. 22, 1912	[4] 1.24	0	1.24	0.74	....	17.5	26.2	26.5
Jan. 24, 1913	0.46	0	....	0.66	9.6	9.6	13.5	....
Jan. 25, 1913	1.15	0	1.35	....	....	19.2	[1] 25.0	25.5
Feb. 28, 1913	0.76	0	....	0.56	13.4	13.4	21.2	....
Mar. 1, 1913	1.41	0	1.57	....	....	21.5	29.5	28.2
Mar. 13, 1913	0.79	0	....	0.78	14.3	14.3	21.0	....
Mar. 14, 1913	0.91	0	1.14	1.16	....	17.8	25.5	....
Mar. 15, 1913	[4] 2.71	0	3.06	....	....	29.3	[1] 35.0	35.1

[1] Estimated rise based on theoretical estimate from rainfall reported at 8 a. m. of the previous day.
[4] Reports covered two dates but rain fell in 24 hours.
[5] Dropped on account of capacity of stream to carry off without a rise.
[6] No consideration given rains in upper section of watershed of Dec. 21, 1911, the two rains being distinct and about 36 hours apart.

RIVER GAGE RELATIONS BETWEEN CARLTON, GA., AND CALHOUN FALLS, S. C., AND AUGUSTA, GA.

While average rainfall is the prime consideration in the predicting of river stages at Augusta, it has been found that when there are complications reference to the river gage readings at Carlton, Ga., on the Broad River, and Calhoun Falls, S. C., on the Savannah River, is frequently of great assistance. Before applying these readings to the problem, however, the forecaster must be reasonably sure the rainfall has had time to cause an approximately maximum rise at the substations named. From a study of the gage relation diagrams for individual rises, the following table has been prepared.

TABLE XVII.—*Relation of the mean of the river stages at Carlton and Calhoun Falls to the ultimate maximum stage at Augusta.*

Average of river stages Carlton and Calhoun Falls.	24 hours later, Augusta—	
	Will reach—	But not over—
Feet.	*Feet.*	*Feet.*
5	18	22
6	20	25
7	21	27
8	22	28
9–10	25	32
11–12	26	33
13–14	28	34
15–16	29	34
17–18	30	35
19–20	31	36
21–22	32	37
23–24	33	37
25–26	34	38
27–28	37	39
29–30	38	40

LATITUDE IN FORECASTING BEST SERVES PUBLIC INTERESTS.

It has been found by experience that the taking of latitude in stating a river forecast for Augusta is frequently desirable, since the information thus conveyed is more complete than it would be if a definite figure were named regardless of the uncertainties involved in the estimate.

When no more rain is indicated and the problem is clean-cut no latitude is necessary.

When no more rain is expected, but the problem involves uncertainties, a latitude of 1 or 2 feet may be taken. In predicting stages above 32 feet a 2-foot latitude should nearly always be taken.

When more rain is expected it is always advisable to take a latitude of 2 feet, as 26 to 28 feet or 30 to 32 feet.

RELATION OF THE HOURLY RATE OF RISE TO THE ULTIMATE STAGE.

So much does the time of the beginning of the rise and the hourly rate of rise at stages under 20 feet depend upon the distance of the heaviest rainfall from Augusta, the rate of rainfall, and soil conditions, that reliable rules of relationship between the hourly rate of rise at such stages and the maximum stage likely to be reached are impossible to calculate. At times when the precipitation is heavy and continuous in that portion of the watershed immediately above Augusta, a night rise from a stage of 10 or 12 feet will reach 20 or 22 feet before it is possible

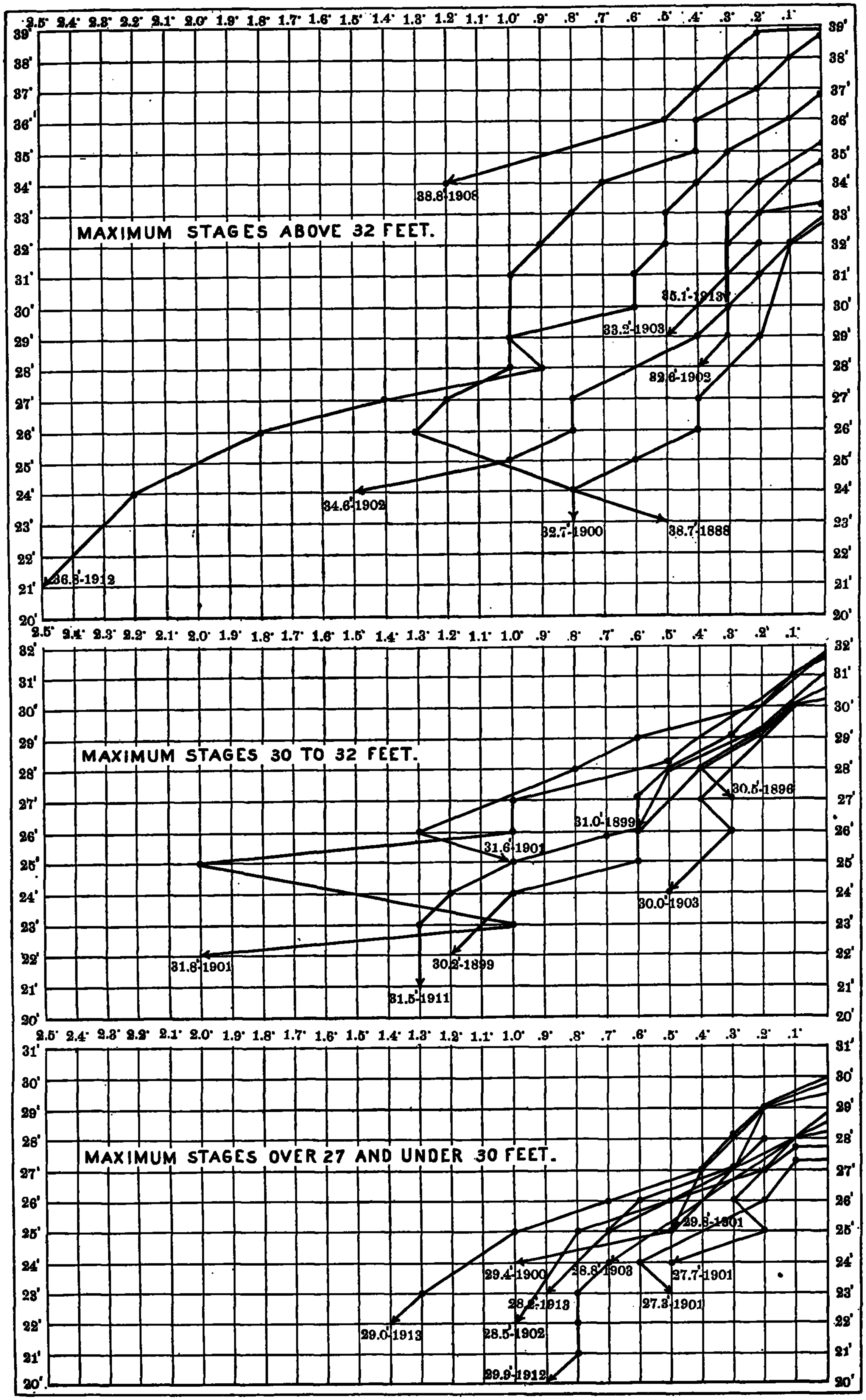

FIG. 4.—River forecast scheme. Diagram No. III. Rate of hourly rise in the Savannah River at Augusta, Ga., for all maximum stages between 27 and 40 feet.

to get reports from the rainfall stations. When these sudden rapid rises occur during the day, special reports greatly assist in the making of accurate and timely forecasts. Usually, however, the river is less responsive to the rainfall over the catchment area and the preparation and dissemination of timely forecasts is attended by no difficulty.

In an accompanying chart (Fig. 4) the hourly rates of rise for all freshets for which the information is available have been plotted. From this chart has been deduced the following table, showing the relation likely to exist between the rate of rise above 22 feet and the ultimate maximum stage. If these figures should at any time become of special importance, they should be used with judgment and due consideration of whether or not rain is still falling or more rain is expected. It may be well to state that a brisk downstream wind will lower the maximum stage sometimes as much as a foot and a half, while an upstream wind will increase it somewhat.

TABLE XVIII.—*Rise to be expected in the Savannah River at Augusta, Ga., for various rates of rise per hour.*

Maximum stage expected to be between 25 and 30 feet.		Maximum stage expected to be over 30 feet.	
Hourly rise.	Indicates further rise.	Hourly rise.	Indicates further rise.
Feet.	*Feet.*	*Feet.*	*Feet.*
0.1	0.5 or less.	0.1	1.0 or less.
0.2	1.0 to 1.5	0.2	1.0 to 2.0
0.3	1.0 to 3.0	0.3	3.0 to 5.0
0.4	2.0 to 3.0	0.4	3.5 to 5.0
0.5	3.0 to 5.0	0.5	3.5 to 5.5
0.6	3.0 to 5.5	0.6	4.0 to 6.0
0.7	3.0 to 6.0	0.7	5.0 to 7.0
0.8	4.0 to 8.0	0.8	5.0 to 8.0
		1.0	6.0 to 10.0
		1.2	8.0 to 12.0
		1.3	9.0 to 13.0

SWAMPS BELOW AUGUSTA.

There is a popular belief that when the swamps in the Savannah basin below Augusta are surfeited with moisture the swamp water acts as an obstruction to the flow of the stream at Augusta and causes higher freshet stages than occur when there is a large unsatisfied storage capacity in the swamps. It has been said that the 1888 stage of 38.7 feet was higher by reason of the swamps being full than it otherwise would have been. The 1908 freshet was, however, one-tenth foot higher, and in that instance the swamp water was low. In assigning these two floods positions in the forecast scheme, both seem fully accounted for by the volume of water received from above Augusta.

Moderate freshets will, of course, inundate farm lands in the river bottoms less readily when a depleted storage capacity in the swamps must first be satisfied, but in large freshets the amount of water thus retained by the swamps is so small as compared with the immense volume of river flow that little benefit can be expected even by the farmers.

When the water is high the sudden slowing of the current in the flat land below Augusta undoubtedly raises the stage at Augusta to some extent, but there seems no reason to believe that the magnitude of this effect is noticeably influenced by the water contents of the swamps. In a report to Hon. Charles Estes, mayor of Augusta, in 1874, Mr. William Phillips, civil engineer, estimated the velocity of the current on the 52-foot drop in 6 miles from Bull Sluice to Hawks Gulley (in Augusta) as 19.50 feet per second and the velocity between Hawks Gully and Butlers Creek, a distance of 12.75 miles with a drop of about 6 inches to the mile, as only 1.75 feet per second.

POWER DAMS ABOVE AUGUSTA.

Since none of the power dams on the Savannah River are designed for the permanent impounding of water in storage reservoirs, their effect upon the stream flow and upon the freshet stages at Augusta may be considered negligible, with the exception of the diurnal fluctuations caused by the manipulations of water in the Augusta Power Canal when stages are below 10 feet.

Reports that dams up the stream have broken are always current when danger stages are reached or expected, and these reports always cause much alarm on the part of the people. Engineers who have been questioned on the subject of possible danger from this source are of the opinion that the washing away of one of the dams, which are submerged by the high water, would have little if any effect on the flood situation.